MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

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REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

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Lieut.-General J. F. TENNANT, C.I.E., R.E., F.R.S., President, in the Chair.

Oliver Joseph Lodge, D.Sc., LL.D., F.R.S., Professor of Physics at the University College, Liverpool,

was balloted for and duly elected a Fellow of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Edward Herbert Lees, Orbost, Victoria, Australia (proposed by R. L. J. Ellery);

John Samuel Slater, Professor of Civil Engineering, Civil Engineering College, Seebpore, Calcutta (proposed by A. M. W. Downing);

J. de Mendizábal Tamborrel, 13 Calle de Jesús, Mexico (proposed by E. B. Knobel);

Arthur Thornton, M.A., Mathematical and Science Master, Giggleswick School, Yorkshire (proposed by E. W. Brown);

William Livingstone Watson, Ayton, Abernethy, Perthshire (proposed by Ralph Copeland).

One hundred and ninety-one presents were announced as having been received since the last meeting, including amongst others:—

J. E. Gore, Star Groups: a student's guide to the constellations, presented by the author; T. Cooke & Sons, On the adjust-

ment and testing of telescopic objectives, presented by the authors; F. W. Very, On the distribution of the Moon's Heat and its variation with the phase, presented by the author; Lick Obsérvtory, Reports of observations of the total eclipse of the Sun, December 21–22, 1889, presented by the Observatory; T. W. Backhouse, The structure of the Sidereal Universe, presented by the author; L. Struve, Bestimmung des Mondhalbmessers, presented by the author; C. Flammarion, Copernic et la découverte du Système du Monde, presented by the author; W. Huggins, Address delivered at the Cardiff meeting of the British Association, presented by the author; Th. von Oppolzer, Traité de la détermination des orbites des comètes et des planètes, trad. par E. Pasquier, presented by Mr. R. E. S. Cooper; J. A. C. Oudemans, Die Triangulation von Java, Abth. III., presented by Professor Oudemans; the Photochronograph and its application to star transits, presented by Georgetown College Observatory; J. K. Rees, Catalogue of Prof. Rutherfurd's photographs, presented by Columbia College; Cincinnati Observatory, Charts and micrometrical measures of nebulæ, presented by the Observatory; Lund Observatory, Observations de la zone $+35°$ à $+40°$, presented by the Observatory; Photographs of the Spectra of Solar prominences, presented by G. E. Hale; Photographs of the Cluster in *Hercules* and of *Jupiter*, taken at the Lick Observatory, presented by Professor Holden; Slater's Armillary Sphere, presented by Professor Slater; two drawings of *Jupiter*, presented by Mr. G. T. Gwilliam.

Note on the Lunar Theory. By Professor Cayley.

In the Lunar Theory, in whatever way worked out, the values ultimately obtained for the coordinates r, v, y should of course satisfy identically the equations of motion; and that they do so is the ultimate verification of the correctness of the results obtained. It can hardly be hoped for that such a verification will ever be made for Delaunay's results; and yet it would seem generally that the labour of such a verification of the results to any extent, while exceeding (and possibly greatly exceeding) that of obtaining these results by any method employed for that purpose, ought still to be, so to speak, a labour of the same order. And one can, moreover, imagine the process of verification so arranged as to be a process of mere routine which could be carried out by ordinary computers. But, however this may be, I think it is not without interest to exhibit the verification to a very small extent, viz. to e, m^4.

I think there is an advantage in using capital letters for the arguments, and I accordingly write G (instead of Delaunay's g), to denote the mean anomaly.

The equations of motion are:

$$\frac{d^2r}{dt^2} - r\left\{\cos^2 y\left(\frac{dv}{dt}\right)^2\right\} + \frac{n^2a^3}{r^2} = \frac{d\Omega}{dr},$$

$$\frac{d}{dt}\left\{r^2\cos^2 y\left(\frac{dv}{dt}\right)\right\} \qquad = \frac{d\Omega}{dv},$$

$$\frac{d}{dt}\left(r^2\frac{dy}{dt}\right) + r^2\sin y\cos y\left(\frac{dv}{dt}\right)^2 = \frac{d\Omega}{dy},$$

$$\Omega = \frac{m'r^2}{r'^3}\left(\frac{3}{2}\cos^2\mathrm{H} - \frac{1}{2}\right), \text{ where } \cos\mathrm{H} = \cos y\cos(v-v'),$$

or say

$$\Omega = \frac{m^2n^2a'^3}{r'^3}r^2\left\{\frac{3}{2}\cos^2 y\cos^2(v-v') - \frac{1}{2}\right\};$$

and thus the equations become

$$\frac{d^2r}{dt^2} - r\left\{\cos^2 y\left(\frac{dv}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2\right\} + \frac{n^2a^3}{r^2}$$

$$= \frac{m^2n^2a'^3}{r'^3}r\left(3\cos\quad\left\{\frac{1}{2} + \frac{1}{2}\cos(2v-2v')\right\} - \frac{1}{2}\right),$$

$$\frac{d}{dt}r^2\cos^2 y\left(\frac{dv}{dt}\right)^2 = \frac{m^2n^2a'^3}{r'^3}r^2\left(-\frac{3}{2}\cos^2 y\sin(2v-2v')\right),$$

$$\frac{d}{dt}\left(r^2\frac{dy}{dt}\right) + r^2\sin y\cos y\left(\frac{dv}{dt}\right)^2 = \frac{m^2n^2a'^3}{r'^3}r^2\left(-3\sin y\cos y\frac{1}{2} + \frac{1}{2}\cos(2v-2v')\right).$$

To simplify as much as possible, take the Sun's orbit to be circular, i.e. $r' = a'$, $v' = mnt$; also neglect y^2: the first and second equations are

$$\frac{d^2r}{dt^2} - r\left(\frac{dv}{dt}\right)^2 + \frac{n^2a^3}{r^2} = m^2n^2r\left\{\frac{1}{2} + \frac{3}{2}\cos(2v-2v')\right\}$$

$$\frac{d}{dt}r^2\cdot\left(\frac{dv}{dt}\right) \qquad = m^2n^2r^2\left\{-\frac{3}{2}\sin(2v-2v')\right\};$$

and if for convenience of working we write $a = 1, n = 1$, then the first equation may be written

$$\frac{1}{r}\ \frac{d^2r}{dt^2} - \left(\frac{dv}{dt}\right) + \frac{1}{r^3} = m^2\left\{\frac{1}{2} + \frac{3}{2}\cos(2v-2v')\right\},$$

and similarly the second equation is

$$\frac{1}{r^2}\ \frac{d}{dt}\left(r^2\frac{dv}{dt}\right) = -\frac{3}{2}m^2\sin(2v-2v),$$

and the third equation may be disregarded.

The two equations should be satisfied by Delaunay's values, putting therein $e' = 0$, $y = 0$; say by the values

$$\frac{1}{r}=1+\frac{1}{6}m^2-\frac{179}{288}m^4$$
$$+\left(m^2+\frac{19}{6}m^3+\frac{131}{18}m^4\right)\cos 2D$$
$$+\left(\frac{7}{8}m^4\right)\cos 4D$$
$$+e\left(1-\frac{7}{12}m^2\right)\cos G$$
$$+e\left(\frac{33}{16}m^2\right)\cos 2D+G$$
$$+e\left(\frac{15}{8}m+\frac{187}{32}m^2\right)\cos 2D-G\,;$$

$$v=t$$
$$+\left(\frac{11}{8}m^2+\frac{59}{12}m^3+\frac{893}{72}m^4\right)\sin 2D$$
$$+\left(\frac{201}{256}m^4\right)\sin 4D$$
$$+2e\quad\sin G$$
$$+e\left(\frac{17}{8}m^2\right)\sin(2D+G)$$
$$+e\left(\frac{15}{4}m+\frac{263}{16}m^2\right)\sin(2D-G)\,;$$

Where

$$D=(1-m)t,\qquad G=\left(1-\frac{3}{4}m^2\right)t,\qquad (v'=mt).$$

The verification for the first equation is

	$\frac{1}{r}\frac{d^2r}{dt^2}=$	$-\left(\frac{dv}{dt}\right)^2=$	$\frac{1}{r^3}=$	$m^2\left(-\frac{1}{2}-\frac{3}{2}(\cos 2v-2v')\right)=$	
Const.		-1	$+1$		$=0$
			$+\frac{1}{2}m^2$	$-\frac{1}{2}m^2$	$=0$
	$+2m^4$	$-\frac{121}{32}m^4$	$-\frac{9}{32}m^4$	$-\frac{33}{16}m^4$	$=0$
Cos 2D	$+4m^2$	$-\frac{11}{2}m^2$	$+3m^2$	$-\frac{3}{2}m^2$	$=0$
	$+\frac{14}{3}m^3$	$-\frac{85}{6}m^3$	$+\frac{19}{2}m^3$		$=0$
	$+\frac{64}{9}m^4$	$-\frac{539}{18}m^4$	$+\frac{137}{6}m^4$		$=0$
Cos 4D	$+8m^4$	$-\frac{161}{16}m^4$	$+\frac{33}{8}m^4$	$-\frac{33}{16}m^4$	$=0$
Cos G	e	$-4e$	$3e$		$=0$
	$-\frac{9}{4}em^2$	$+em^2$	$-\frac{3}{4}em^2$		$=0$
Cos 2D + G	$e\,\frac{193}{16}m^2$	$e\left(-\frac{73}{4}m^2\right)$	$e\left(\frac{147}{16}m^2\right)$	$e(-3m^2)$	$=0$
Cos 2D − G	$em\left(\frac{15}{8}\right)$	$em\left(-\frac{15}{2}\right)$	$em\left(\frac{45}{8}\right)$		$=0$
	$em^2\left(-\frac{5}{32}\right)$	$em^2\left(-\frac{187}{8}\right)$	$em^2\left(\frac{657}{32}\right)$	$em^2(3)$	$=0$

That the second equation is

	$\frac{2}{r}\frac{dr}{dt}\cdot\frac{dv}{dt}=$	$+\frac{d^2v}{dt^2}=$	$+\frac{3}{2}m^2\sin(2v-2v')=$	
Sin 2D .	$+4m^2$	$-\frac{11}{2}m^2$	$+\frac{3}{2}m^2$	$=0$
	$+\frac{26}{3}m^3$	$-\frac{26}{3}m^3$		$=0$
	$+\frac{142}{9}m^4$	$-\frac{142}{9}m^4$		$=0$
Sin 4D	$+\frac{21}{2}m^4$	$-\frac{201}{16}m^4$	$+\frac{33}{16}m^4$	$=0$
Sin G	$e\,.\,2$	$+e\,.\,-2$		$=0$
	$e\,.\,3m^2$	$+e\,.\,3m$		$=0$
Sin 2D + G	$e\,.\,\frac{129}{8}m^2$	$e\,.\,-\frac{153}{8}m^2$	$e\,.\,3m^2$	$=0$
Sin 2D − G	$e\,.\,\frac{15}{4}m$	$e\,.\,-\frac{15}{4}m$		$=0$
	$e\,.\,\frac{71}{16}m^2$	$e\,.\,-\frac{23}{16}m^2$	$e\,.\,-3m^2$	$=0$

and the verification is thus completed.

The following intermediate results may be recorded ; $\frac{1}{r}=1+\chi$,

	$\chi^2=$	$-$ og $r=$	$\frac{dv}{dt}=$
	$\frac{19}{36}m^4$	$\frac{1}{6}m^2-\frac{255}{288}m^4$	1
Cos 2D	$+\frac{1}{3}m^4$	$m^2+\frac{19}{6}m^3+\frac{64}{9}m^4$	$\frac{11}{4}m^2+\frac{85}{12}m^3+\frac{539}{36}m^4$
Cos 4D	$+\frac{1}{2}m^4$	$\frac{5}{8}m^4$	$\frac{201}{64}m^4$
Cos G	$+\frac{1}{3}em^2$	$e\left(1-\frac{3}{4}m^2\right)$	$e\left(2-\frac{3}{2}m^2\right)$
Cos 2D + G	$+em^2$	$e\left(\frac{25}{16}m^2\right)$	$e\left(\frac{51}{8}m^2\right)$
Cos 2D − G	$+em^2$	$e\left(\frac{15}{8}m+\frac{171}{32}m^2\right)$	$e\left(\frac{15}{4}m+\frac{143}{16}m^2\right)$

	$\frac{1}{r}\frac{dr}{dt}=$
Sin 2D	$2m^2+\frac{13}{3}m^3+\frac{71}{9}m^4$
Sin 4D	$\frac{5}{2}m^4$
Sin G	$e\left(1-\frac{3}{2}m^2\right)$
Sin 2D + G	$e\left(\frac{75}{16}m^2\right)$
Sin 2D − G	$e\left(\frac{15}{8}m+\frac{51}{32}m^2\right)$

These were in fact made use of for finding the foregoing values of r, $\frac{d^2r}{dt^2}$, &c.

Colour Changes in the Markings on the Surface of the Planet Jupiter. By E. E. Barnard.

During the twelve years that I have observed *Jupiter* I have often been struck with the decided changes of colour in the different markings on his surface. A careful study of the numerous details during this time has led to the discovery that the red colour of any of the markings is an indication of their age; or, in other words, when a spot or marking (other than the white spots) first appears it is dark or black, but after some time turns red. I have repeatedly predicted to myself this transition upon the appearance of a dark spot, and have yet to find the first instance of a deviation from this striking rule.

As an illustration, I would mention a few cases in my own experience. The remarkable black spots of 1880 which appeared on the northern hemisphere of the planet in October and November of that year were at first black, and then terminated their career by forming a red belt around *Jupiter* (see *Publ. A. S. P.* No. 5).

The small inky-black spots which appeared on the northern edge of the equatorial belt in 1890 soon turned red, and are now almost the reddest objects on the planet.

The new red spot, which lies on a parallel with the southern edge of the great red spot, and follows it by about 140°, when first seen by me in the early part of August 1890, was dark, with no trace of red. It is now the most conspicuous object on the planet, and is of a deep red colour.

There is another marking similar to this in the same latitude, and preceding the great red spot by an hour or so. When first seen this was dusky, with no trace of red. On August 14 last I wrote in my note-book: "This dusky oblong marking has no trace of red now; perhaps it will turn red." It is now of a strong red colour.

I have noted this transformation in a number of other cases. It would, therefore, appear certain that as a rule markings of this class first appear dark, and later turn red.

I have been curious to know if the great red spot in its early history was also governed by this rule. When I first saw it in 1879 it was a deep red, and has been so ever since, except where partially obscured by white clouds, during the past six or seven years. I have fortunately found two early observations of this spot in 1872. These fully prove that the great red spot is no exception to the rule. In the *Observatory* for 1882, vol. v. p. 21, Mr. H. Corder says, in speaking of his observations of this object in 1872, March 13: "Its colour was not noted as red." In the same volume, p. 55, M. Terby confirms Mr. Corder's statement about the absence of colour in the spot. He has an observation 1872, January 28, and, referring to this, says: "I ought

to say, with Mr. Corder, that I did not remark any special tint in this spot. I observed it merely as a dark spot, grey or black, with the *same* instrument which to-day shows me the red colour of this remarkable object in so striking a manner."

From a knowledge of the time occupied by the dark phase of the spots, I think it would be safe to say that the great red spot was not many months old when seen by Mr. Corder and M. Terby in 1872.

This rule seems to apply also to the equatorial belts. The darker portions would therefore appear to be new or recent formations.

Mount Hamilton:
1891 *September* 30.

Observations of the Spots and Markings on the Planet Jupiter, made with the Twelve-inch Equatoreal of the Lick Observatory. By E. E. Barnard.

I have already communicated a series of observations and measurements of the markings on the planet *Jupiter* to the Royal Astronomical Society. I have continued these observations this year, and herewith present the results.

The planet has been extremely interesting at this opposition, from the remarkable amount and variety of detail displayed upon his surface. As usual, the two hemispheres have been strongly contrasted in their individual markings. In the southern hemisphere, besides the great red spot, new red spots have appeared, and a great number of round white spots have been visible. These objects are characteristic of the southern hemisphere, though individual white spots have at rare intervals been seen in the northern hemisphere. In the northern half of the planet a system of small dark spots has appeared. These have extraordinary short periods of rotation. The northern regions have also exhibited many features of detail. These have, however, been dark and obscure.

The great red spot has regained much of its former distinctness both in colour and form.

Observations have been made of the relative light and size of the four satellites. These will be continued. The fourth satellite seems to vary considerably in its light.

The following observations and remarks are the result of an examination of the planet with the 12-inch equatoreal of this observatory. The times are Mount Hamilton mean time.

The transits have been obtained by bisecting the equatorial belts by a vertical micrometer wire, and noting when the object passed behind this wire.

In the tabulation of the measures, N means distance from north limb of the planet, and S the reverse.

Small Oblong Dusky Spot in the Southern Hemisphere.

		Transit	λ	N.	N. 5·20	S.	S. 5·20
		h m	°	″	″	″	″
1891 Sept.	21	11 17·4	214·4	...	...	...	...
Oct.	4	6 51·3	208·3	35·7	28·1	10·1	8·0
	8	10 11·2	209·9	...	...	...	...

On Oct. 4 the length of this object was 1″·7, and its breadth 0″·8. Dark at first, it gradually assumed a tinge of red. On the last date, a very small spot closely preceded it. Its longitude diminishes about 0°·47 daily.

Small Black Spots in the Northern Hemisphere.

In 1880, during October and November, it will be remembered, a number of remarkable black spots broke out on a fine linear belt just north of the equatorial belts. These objects were possessed of an extraordinary relative motion. After many singular and remarkable transformations, they finally formed a diffused red belt about the planet.

During the present year, a number of small dark spots have appeared in identically the same location. They also have an extraordinary velocity of rotation. With the exercise of a good deal of care, I have succeeded in identifying certain of these spots, and have observed them at different transits..

Following are the observations of these interesting markings. They are all located in the same latitude:—

Spot a.

		Transit	λ	N.	N. 5·20.	S.	S. 5·20.
		h m	°	″	″	″	″
1891 Sept.	17	8 51·4	244·9	16·0	12·3	31·5	24·2
	21	11 1·6	205·9	...	...	...	...
Oct.	2	12 6·2	97·9	...	...	...	...

This is the following of three.

Spot b.

		Transit.	λ
		h m	°
1891 Sept.	28	7 45·3	58·7
Oct.	4	11 3·1	0·2
	5	6 42·8	353·2
	7	7 45·0	331·4

The following of three.

Spot c.

		Transit.	λ
		h m	°
1891 Sept.	28	7 0·9	31·9
Oct.	2	9 15·7	354·7
	7	7 9·2	309·8

The first of three.

Spot d.

	Transit.	λ
	h m	°
1891 Oct. 4	9 38·8	309·3
7	6 30·2	286·3

This is an isolated spot.

Following are transits of a few more of these dark spots which I have not identified with certainty at successive observations, though some of them may be identical:—

	Transit.	λ	
	h m	°	
1891 July 11	14 0	285·0	Isolated spot.
Sept. 3	7 59·7	268·1	The first of three.
18	10 19·5	88·4	The first of three. Perhaps the first of a chain of spots.
Oct. 4	6 46·6	205·3	The second of two isolated spots.
5	7 24·3	18·1	First of a chain of dark spots.

All the foregoing spots are located on a narrow belt in the northern hemisphere, the position of which on September 9 was

Distance from North limb = 14″·8 one obs.

Distance from South limb = 32·9 one obs.

The spots extend in a broken chain around the planet and have a relative motion (when referred to Marth's Meridian II.) of 9°·80 daily. They complete a revolution around *Jupiter* in about 37 days. They were first seen by me.

The New Oblong Red Spot in the Southern Hemisphere.

The history of this object dates from last year. It rather rapidly formed near the great red spot, as an oblong dusky marking in the first part of August 1890. Like the other new red spot now visible on the southern hemisphere, its first appearance near the great spot might suggest some connection with that object and their origin.

Its longitude diminishes about 0°·54 daily. It is clearly defined and of a strong red colour—by far the most noticeable object on the planet. Its period of revolution around *Jupiter* is about 667 days, or less than two years, as referred to the great red spot. Its motion may be slightly variable. About 1892, June 1, it will again pass the red spot, skirting the southern edge of that object at its nearest approach.

	Transit.	λ	S.	S. 5·20	N.	N. 5·20.	Length.	L. 5·20.
	h m	°	″	″	″	″	″	″
1891 July 13	12 44	179·6	11·3	9·5	32·2	27·1	8·4	7·0
25	12 33	177·2	11·1	9·0	33·7	27·4	9·3	7·6
30	12 25·4	168·3	10·8	8·6	33·8	27·0	10·1	8·0
Aug. 1	13 5·9	169·8	...	...	...	...	...	...
9	9 35·4	165·9	...	...	...	...	...	...
21	9 15·7	158·6	...	...	...	...	...	...
23	10 52·8	158·4	11·7	9·0	34·9	26·8	...	...
28	9 54·4	155·1	11·5	8·8	34·6	26·5	...	...
Sept. 7	8 2	151·5	...	...	...	...	...	...
16	10 17·3	146·3	11·2	8·6	34·5	26·5	...	...
18	11 51·9	144·2	11·4	8·8	34·7	26·7	...	...
Oct. 3	9 3·8	137·7	...	...	...	...	...	...
6	6 32·1	136·9	11·0	8·7	34·6	26·7	...	...

The apparent breadth of this object on July 25 was 0″·8.

There was a small white spot at its preceding end throughout the observations.

The Large White Spots in the Southern Hemisphere.

I have observed several of these objects. Their rotation periods are about the same as those of the new red spots. Their longitudes decrease about 0°·6 daily.

Spot A.

	Transit.	λ	N.	N. 5·20.	S.	S. 5·20.
	h m	°	″	″	″	″
1891 July 27	12 46	125·9	...	...	...	...
29	14 16	121·0	...	...	...	...
Aug. 1	11 48	122·7	...	...	...	...
8	12 26·5	118·7	...	...	...	...
10	13 58	114·9	35·4	27·7	9·6	7·6
23	9 35·7	111·8	36·2	27·8	10·6	8·1
25	11 11·1	110·0	...	...	...	...
Sept. 16	8 53·5	95·6	35·6	27·4	10·3	7·9
18	10 32·0	95·9	...	...	...	...

Spot B.

	Transit.	λ	S.	S. 5·20.	N.	N. 5·20.
	h m	°	″	″	″	″
1891 Aug. 12	12 40	8·6	...	...	...	...
20	9 4·6	1·6	10·1	7·8	36·7	28·2
27	9 42·1	357·4	10·9	8·4	36·4	27·9
Sept. 8	Transit not obsd.		10·6	8·1	36·6	27·9
17	11 41·1	347·4	11·3	8·7	35·7	27·5

This was a very luminous spot, which passed close, skirting the southern edge of the great red spot. Measurements were made of its position to detect any displacement in latitude during its passage of the red spot.

The latitude did not sensibly change, and the great spot seemed to exert no repellent force against it.

It was first seen in the first part of August, when it was taken for a satellite in transit.

Spot C.

	Transit.	λ	N.	N. 5·20	S.	S. 5·20.
	h m	°	"	"	"	"
1891 Sept. 11	8 56·5	65·5	35·8	27·4	10·3	7·8
16	7 54·7	60·2	36·7	28·2	9·4	7·2
Oct. 3	6 35·2	48·0	...	...	...	...

This object has a peculiar wisp of dusky matter extending southwards from it.

Long Red Spot in Southern Hemisphere.

	Transit.	λ	Length.	L. 5·20.
	h m	°	"	"
1891 Sept. 17	10 17·3	296·8	...	...
Oct. 2	7 16·0	282·5	14	11
7	6 24·3	282·7	12	10

This object was first seen some time previous to August 12, when it was south preceding the great red spot. It was then dark, with no trace of red. From August 21 it began to turn red, and by September 17 was of a strong red colour. The first two transits are rough, and the measures of its length are very approximate. It is in a latitude very slightly south of that of the southern edge of the great red spot. These remarkable red strips, now so prominent in the southern hemisphere, seem to have their origin in the region of the great red spot, where they first appear as dark markings.

The Great Red Spot.

The great red spot seems to be stationary in longitude; the motion appearing to be the same as that assigned to Marth's System II. If this is so, the following observations would indicate a probable error of $\pm 0^{\circ}\cdot 44$ or $\pm 0^{m}\cdot 73$ in the determination of the time of transit by a single estimate.

Professor Hough, from a fine series of micrometer measures, in 1880, deduced a probable error of $\pm 0^{m}\cdot 9$ in the time of transit from a single pair of measures, and thinks the micrometer method far preferable to any method of eye-estimates. Careful eye-estimates, however, I think, should have the same value as micrometer measures for determining the lines of transit of the spots on *Jupiter*. I have had a few previous remarks on this subject in a paper on the planet, printed in No. 5 of the *Publi-*

cations of the Astronomical Society of the Pacific. (See pp. 91–92).

The colour of the great spot has been much stronger this year, and its form more definite than for a good many years. It still remains the slowest rotating object on the planet.

I have been in hopes that some of the round white spots—so abundant in the southern hemisphere—would make their appearance in the same latitude as the red spot, so that their motion would carry them over or under it; but they seem to be confined to a region the northern limit of which is parallel with the southern edge of that spot.

One object, apparently connected with the history of the red spot, and which was a prominent feature last year, has been wholly missing during the present apparition of the planet: this was a curious reddish streak emanating from the southern edge of the equatorial belt north preceding the red spot, and which, curving southwards, passed along parallel to the equatorial belt in a preceding direction. It was a perfectly symmetrical outline of the "bay" formed north following the red spot by the equatorial belt. This was visible throughout last year, and seems to be a recurring feature, since it has repeatedly appeared and disappeared within the past twelve years, alway appearing in the same position. The "bay" referred to has been very marked this year.

Careful examination, under the best conditions this year, have shown that the dark belt south of the red spot is entirely free from the edge of that object, a clear space of about ¼″ being visible between them.

The observations seem to show that the great spot is shorter this year than in 1880, and it is perhaps broader.

Following are observations of this object:—

		Transit	λ	Apparent Length.	L 5·20	N.	N. 5·20	S.	S. 5·20
1891		h m	°	″	″	″	″	″	″
June	3	...	...	9·5	9·1	...	...	...	...
	5	16 27·3	3·2	...	...	...	...	...	...
July	14	13 38·3	2·8	...	...	...	...	...	...
Aug.	2	14 15·0	2·0	...	...	...	...	...	...
	12	12 31	3·1	...	...	...	...	...	...
	20	9 26	2·5	...	...	...	...	...	...
	27	9 54	4·3	...	...	...	...	...	...
Sept.	3	10 37·2	3·3	...	...	...	...	...	...
	17	12 6·0	2·4	...	...	...	...	...	...
	18	7 57·4	2·5	12·7	9·8	32·2	24·7	13·3	9·8
Oct.	2	9 29·6	3·1	...	...	32·4	25·4	13·7	10·7
	5	6 57·7	2·2	...	...	...	...	...	...

Width Sept. 18 = 6″·0 (4″·7 at Δ 5·20).

The preceding end transited 1891, June 3^d 15^h $11^m \cdot 7$, giving $\lambda = 16^\circ \cdot 9$.

The two principal members of the system of small dark red spots which were visible last year on the northern edge of the equatorial belt, and which I have designated as spots 1 and 2, have been regularly observed and measured this year. Though not as conspicuous as when seen in April of last year, they are very distinct, and of a deep red colour. Last year the measures did not indicate with certainty any relative motion in the two. This year, however, the distance between them has diminished considerably—about 2″. The latest observations show that the distance reached a minimum in the end of August, and seems now to be slowly increasing.

Mean distance 1890 . . .	7″·64
Mean distance 1891 . . .	5·58

I have collected my observations made of these spots this year in the following table, where Δ is the observed distance between them and Δ 5·20 the value at *Jupiter's* mean distance. The measures under the headings N and S are the measured distances from the north and south limbs of the planet.

Since the first observations of these spots in 1890 April 26, they have slowly drifted through 104° of longitude at the rate of 0°·253 daily. They will make a complete revolution about *Jupiter* in 3·9 years.

	Spot 1.	λ	Spot 2.	λ	Δ	Δ 5·20	N.	N. 5·20	S.	S. 5·20
1891	h m	°	h m	°	″	″	″	″	″	″
July 4	12 33	259·9	...	...	7·4	6·4	15·9	13·7	25·6	22·1
28	12 9	254·1	12 43	257·2	8·2	6·6	17·7	14·2	26·8	21·6
Aug. 9	12 1	254·1	...	...	7·0	5·5	17·8	14·0	27·5	21·6
14	...	...	11 35·1	270·2	6·5	5·1	17 7	13·8	28·5	22·2
19	10 11·9	252·2	...	...	7·3	5·2	...	...	...	...
24	...	...	9 41·6	265·7	6·0	4·6	...	...	...	...
Sept. 7	10 42·3	248·1	...	...	6·7	5·1	18·2	13·9	28·3	21·6
9	...	...	12 51·1	266·6	...	...	...	...	...	...
17	10 39	244·9	...	...	7·0	5·4	18·3	14·0	29·5	22·6
26	...	...	11 41·1	261·6	7·3	5·7	18·6	14·5	29·3	22·7
Oct. 3	11 58·2	243·0	...	...	7·8	6·1	...	...	...	...
4	7 42·1	238·8	8 13·1	257·5	7·2	5·7	17·7	13·9	27·6	21·8

Phenomena of the Satellites.

1891 July 11^d 13^h 39^m 6^s. Reappearance of II. from occultation. Bisection.

1891 July 27^d 12^h 53^m 43^s. Transit of II. egress. Bisection.

1891 August 10^d 13^h 59^m 24^s. Conjunction of I. and II.

The two satellites appeared like a close double star, but well separated.

1891 August $12^d\ 11^h\ 58^m\ 13^s$. Central transit of III. It crossed the bright surface of *Jupiter* as a large dark grey spot. The following are measures of its position at mid-transit:—

From South limb . . .	11″·7
From North limb . . .	34·0

1891 August $12^d\ 12^h\ 5^m\ 12^s$. Reappearance of II. from occultation. Bisection.

1891 August $21^d\ 8^h\ 58^m\ 33^s$. Transit II. egress. Bisection.

1891 Oct. 1^d, between 9^h and 10^h. III. in transit as a dark spot.

1891 October $6^d\ 6^h\ 42^m\ 25^s$. Transit I. egress. Bisection.

1891 October $6^d\ 7^h\ 13^m\ 13^s$. Transit, egress IV. Bisection. Position at $6^h\ 22^m{\cdot}2$.

From North limb . . .	36″·2
From South limb . . .	8·6

It appeared as a large very dark spot, and was dark up to the moment of egress.

Phenomena of the First Satellite.

The first satellite has been observed on all favourable occasions with the 12-inch, to determine, if possible, the explanation of the phenomenon of 1890, September 8, when it appeared distinctly double at transit.

As I have previously remarked, the conditions for a reobservation of that phenomenon will not be suitable until at least 1892, since the satellite now transits the southern dark equatorial belt, and therefore cannot be seen dark in transit.

My observations have been confined principally to the 12-inch, the scale of which is too small to settle definitely the phenomena exhibited in the transits of the satellites. On several occasions I have, however, been able to examine the satellite in transit with the 36-inch refractor.

The phenomena seen on these occasions would rather discourage the idea of actual duplicity. At these times the satellite has appeared egg-shaped when in relief on the dark belt.

This elongation cannot be due to any malformation of the satellite, since that object has always appeared perfectly round only a few minutes before the elongated phase, the transition being rather sudden. I am confident that this particular phase, and perhaps also that of apparent duplicity, is explained by a bright belt on the satellite, or by darkness of its polar regions, which is the same thing. This I have explained in a previous communication (*Monthly Notices*, vol. li. 557). I cannot, however, account

for the egg-shaped appearance of the satellite, unless it be due to a local excursion of the darker polar caps towards the equator of the satellite. If such is the case, I. must rotate on its axis in a time different from that of its period of revolution, as I have seen this pointed or wedge-shaped appearance sometimes preceding and at other times following the centre of the satellite, at observations separated by no great intervals, and this in the same position on the disc of *Jupiter* (1891 August 3, small end preceding. September 11, small end following. September 18, small end following).

At times this elongation is perfectly parallel to the belts of *Jupiter*; at other times it is inclined 7° or 8° to them. In my previous communications on this subject I have spoken of the position angle of apparent duplicity or elongation. I should have stated that these position angles were referred to the north pole of *Jupiter*, and not to a celestial meridian.

Following are notes with reference to the subject in hand:—

1891 July 4^d 13^h 27^m 13^s, with the 12-inch, the first satellite bisected at transit egress. Before emergence it was seen as a dusky spot, apparently round. At last contact it was certainly perfectly round.

1891 July 11, with the 12-inch. Carefully watched for a dark transit of I. After entering some distance, the satellite entirely disappeared, blending into the dark belt. Its shadow was black and round when well on the disc. At 15^h the satellite was visible as a small pale white spot on the south belt.

1891 July 27, with the 12-inch. Carefully watched the satellite. It became visible as a very faint dark spot when about one-fifth across. At 12^h 13^m it was near the middle of its path. It was impossible to make out its form, since the contrast was too small. The shadow was round.

1891 August 3. The satellite observed in transit with the 36-inch. Shadow was large and round when well on the disc at $13^h\frac{1}{2}$. I. was very much elongated. It was egg-shaped, the small end preceding. Position angle (from Jupiter's north pole) 265°±. The observations on this date have already been sent to the *Monthly Notices*.

1891 September 4. 36-inch. The satellite transited partly covering its shadow. It could not be seen when in mid-transit, but became visible when about four-fifths across. It then appeared perfectly round and partly overlapped its shadow, which appeared as a crescent, joining the north preceding side of the satellite. There was no marking of any kind visible on I., which was watched until egress. Mr. Burnham observed the transit with me.

1891 September 11. 36-inch. Mr. Burnham and I carefully examined I. in transit. The seeing was very poor, but occasionally, during moments of good definition, the satellite was decidedly elongated to both of us. It was egg-shaped with the small end following. The elongation was parallel to the belts of

Jupiter. These observations were made when the satellite was one-fourth across. It was examined again when about four-fifths across. The elongation and egg-shaped appearance were the same, but the seeing had become so poor that its form could not be clearly distinguished at exit.

1891 September 18. 36-inch. Mr. Burnham and I examined the satellite in transit. Before entrance it was perfectly round, and there seemed to be a small dark spot in its centre, which may have been optical. It remained round for a short time after entering upon the planet, but when about one-sixth across, it became elongated in a line perfectly parallel with the belts of *Jupiter*. The elongation was conspicuous. Both Mr. Burnham and myself agreed as to the rapid transition from a round to an elongated object. The following end of the satellite was unquestionably the smaller. The elongation was as nearly as may be 2×3. Watched it closely from the time of contact at entrance until $0^h\ 20^m$ sidereal. Seeing $=4$. During this time, II. following the planet was round.

1891 October 3. 12-inch. The satellite was examined before transit, when it was perfectly round; it was also round at entrance. It soon became lost in the dark belt. The scale of the 12-inch was too small to be certain of its form when disappearing, but it seemed to be elongated. Bisection at entrance $10^h\ 1^m\ 41^s$. The seeing was perfect.

The Nature of the Surface of Jupiter.

After observing the planet for some twelve years I can hardly advocate the theory that the visible surface of *Jupiter* is a cloud surface.

It would seem to me more consistent with the observed phenomena to suppose the surface to be in a plastic or pasty condition, the belts and markings being merely discolorations in this, due to internal eruptions. This would easily account for the observed permanence of certain of the markings and for their colours. I do not think the cloud theory can account at all satisfactorily for the continued permanence of the various markings. The colours and changes of colour are also against it. If we assume the plastic theory, it is readily seen how the dark markings may be matter brought up to the surface by internal disturbances, and which by exposure on the surface is subject to changes of form and colour. Or possibly one might combine the two theories, and account for any shortcomings in the plastic theory by supposing local clouds of steam near or on the surface. I do not know to what extent the small density of the planet may militate against this, but the theory certainly seems worthy of consideration.

Perhaps this idea has been advanced before, as it seems a natural one: if so, I have not seen it.

Mount Hamilton:
1891 *October* 9.

On the supposed Duplicity of the First Satellite of Jupiter. By A. Stanley Williams.

With reference to the remarkable apparent duplicity of the First Satellite of *Jupiter* observed by Mr. Barnard on September 8, 1890, and of which he gives an account in the *Monthly Notices*, vol. li., p. 547, I would ask whether it is quite certain that the observed phenomenon may not have been due to the satellite being seen in transit as a dark spot close to a dark spot on the surface of *Jupiter*. Such an explanation would, of course, be out of the question in the case of an observer of so much experience as Mr. Barnard, if the observation could have been continued during a considerable part of the time that the satellite was on the disc of the planet, since the difference in the rate of motion of the two spots could not in such case have escaped being noticed. But Mr. Barnard expressly states that the observation was interrupted, and that it was not possible to follow the satellite closely owing to the presence of visitors. And the explanation now suggested assumes greater probability when considered in connection with the observation referred to below, since it will appear that there was actually a little spot on the surface of the planet exactly in the position necessary to give rise to the observed duplicity. The explanation ingeniously set forth by Mr. Barnard in his note on p. 557 of vol. li. of the *Monthly Notices* appears to me inadequate to account for the observed appearance, since it would require the satellite to be much larger than it actually is.

On September 5, 1890, three days before Mr. Barnard's observation, *Jupiter* was observed by the writer with a $6\frac{1}{2}$-inch Calver reflector, powers 150 and 225. A little dark spot was noticed in the middle of the bright equatorial zone, exactly in the position of the southernmost component of the double spot represented by Mr. Barnard in his figure (Plate 14, fig. 4). The spot was slightly oval in shape, and about 1″ in length. It was observed to be in mid-transit at $8^{h}\ 42^{m}\!\cdot\!8$. It therefore followed the zero meridian of System I. of Mr. Marth's Ephemeris (*Monthly Notices*, vol. l., p. 346), by $3^{h}\ 30^{m}\!\cdot\!7$. The motion of the markings in the equatorial region of *Jupiter* agreed closely last year with this ephemeris, so that in an interval of a few days there would be no appreciable difference.* The little dark spot would therefore have transited at $15^{h}\ 26^{m}\!\cdot\!7$ G.M.T. on September 8. According to the *Nautical Almanac* the

* The above spot was so small and delicate that, in the unfavourable position of the planet last year, it could not be continuously observed. But a little preceding it was another similar, but larger and plainer, spot, and the

first satellite was in mid-transit on that night at $15^h\ 27^m$, and it would be seen projected on the bright surface of the equatorial zone just north of the planet's equator. Consequently, when in mid-transit, the satellite would have been seen as a dark spot just north of the above-mentioned spot, and the two would have appeared as a close double spot. In other words, the appearance would have been almost exactly that represented by Mr. Barnard in fig. 4, Plate 14. Whether this explanation be considered sufficient or not, it appears to me very important that the presence of this little dark spot should be placed on record.

In conclusion, I may mention that the first satellite was visible in dark-transit on July 26, 1890, in nearly the same position relative to the belts as the northernmost of the two spots shown in Mr. Barnard's sketch, but a little nearer to the equator. Since the elevation of the earth above the plane of *Jupiter's* equator was $-0°{\cdot}297$ on July 26, compared with $-0°{\cdot}402$ on September 8, the position of the satellite on the latter date should have agreed very closely with that of the northernmost of the two spots in fig. 4, Plate 14.

Burgess Hill:
1891 *November* 7.

Note on some Photographs of Jupiter taken with the Five-foot Reflecting Telescope. By A. A. Common, LL.D., F.R.S.

A new mirror for the 5-foot telescope was completed in July, and some experiments have been made in photographing *Jupiter* to determine the exposure necessary and the definition obtainable. With the primary image a good picture is obtained with the quickest exposure that can be given by hand. About 2^s gives a dense image and all the visible satellites, with an enlarging lens giving an image of about $\frac{1}{2}''$ 3^s to 6^s gives ample density, up to 1 inch from 8^s to 10^s gives sufficient density. For further enlargement the time is, of course, proportional. About $1\frac{3}{4}$-inch diameter is the largest we have tried, but this was done on an unfavourable night.

following observations of it will show that its motion did not differ greatly from Mr. Marth's System I.:—

Date.	G.M.T. of Transit.	Longitude. System I.
1890.	h m	°
Aug. 1	11 46·5	111·4
3	13 5·8	115·8
Sept. 9	10 55·6	121·1
Oct. 9	9 23·2	119·9
12	6 20·5	121·9

It was also seen on September 5, but the time of its transit was not recorded.

With regard to the definition, the detail on the planet is not so well given as in the Lick photographs, though closely approaching in the best photographs to this. With an enlargement to a diameter of ·8 of an inch, the satellites are fairly round, and about the proportionate size, though rather faint, the exposure being about 7^s. These photographs were taken with this exposure for the planet, and I did not expect to see any trace of the satellites. Photographs taken on this night, September 8, at short intervals of time, show Sat. II. emerging from the limb, while the shadow is still visible on the disc. When the satellite is well clear, the shadow seems to cut a piece out of the limb.

Another photograph on September 10 shows this with Sat. III. in a similar manner.

Several photographs taken on September 15 show Sat. II. and its shadow in transit. The red spot shows in a most marked manner in many. From an examination of the enlarged image of the planet, and also of the limb of the Moon, it appears to me that definition depends very much on the atmospheric conditions. In looking at the image enlarged on very fine ground glass, there are moments when the image is very sharp and steady. Then the image becomes blurred, and good definition disappears for a few seconds. The nights have been too few to determine whether this is a permanent condition of things, probably there may be nights when the definition is good continuously.

The Reappearance of Saturn's Ring. By the Rev. A. Freeman, M.A.

With the aid of a 6-inch refractor by Simms, lent to me by the Royal Astronomical Society, and having a focal length of 7 feet and a magnifying power of 180, I have fortunately obtained very fine views of *Saturn* in the early mornings of October 29, 30, 31, November 2 and 3. The sky was unhappily overcast on November 1, and from November 4 to 9. The description of what was seen follows:—

October 29, 5^h 55^m A.M. (civil time).—*Saturn's* elliptical disc is crossed by a dark band, its breadth about one-tenth of the length of the polar diameter of the planet. The north edge of this band seems to be on the equator of the planet. The equatorial bright belt, which is yellowish, seemed about half the breadth of the dark band, which is, of course, the unilluminated north side of the rings. I could see no division in this band. The first southern dusky belt is visible, and the rest of *Saturn's* disc is of a pale white colour except at the poles, which are dusky. The crescent moon is only about 4° to the east of *Saturn* and nearly at the same altitude. *Titan* ceased to be visible at 6^h 30^m.

October 30, 6^h 10^m A.M. to 6^h 20^m A.M.—The best view at 6^h 15^m A.M. The broad dark band across *Saturn's* elliptical disc is wholly south of the equator, with its north edge almost on the equator. The band is very sharply defined, and is of an indian-ink colour, the general colour of the brighter parts of *Saturn* pale white, that of the equatorial bright belt a pale yellow. The breadth of the band estimated to be one-tenth of the length of the polar diameter. The south edge of the band seemed to be *very slightly curved*, with convexity southwards. The breadth of the equatorial bright belt is to-day about two-thirds that of the dark band. Two dusky belts visible south of the dark band and one north. The north pole a shade darker than the south pole.

October 31, 6^h 25^m to 6^h 35^m A.M.—The view at 6^h 30^m A.M. showed the broad dark band very distinctly, its north edge on *Saturn's* equator. The yellowish equatorial bright belt north of the equator *is as broad as the band*, which seems a little narrower than yesterday. The distance of the band from a dusky belt south of it is equal to the breadth of the band. There is not to-day, nor was there on the two previous days, any trace whatever of the ansæ of *Saturn's* ring. At 6^h 32^m A.M. a remarkable bright round spot was entering over the east limb of *Saturn* upon the equatorial bright belt, and it was wholly within the limb and wholly upon the bright belt at 6^h 36^m. It appears to follow spot 2^a of Mr. A. S. Williams's spots (*Astron. Nach.* No. 3051) about half a rotation. Mr. Williams confirms this view.

November 1, 6^h A.M.—The sky wholly overcast with clouds. The same was the case, as I am informed, at Cambridge Observatory.

November 2, 5^h 30^m.—On the very first view the ring was plainly visible as a fine bluish line of some breadth on the preceding side, its length about five-eighths of the diameter of *Saturn*; it was also seen, but not so easily, as a faint bluish narrower line on the following side, and of nearly the same length. The power used was 150 only. *Enceladus*, *Tethys*, *Rhea*, *Titan* and *Iapetus* were also visible. (*Dione* was not seen separate from *Rhea*, it was probably closer to *Rhea* than the 8″ which would be given by Marth's Ephemeris.) I soon changed to the higher power of 180, which also has better definition, and at 5^h 45^m A.M., I found the breadth of the blue ansæ at the limb to be equal to that of the dark band, very nearly if not quite. The colour of the ansæ was a vivid electric-light blue, streaked with white in general direction nearly parallel to *Saturn's* equatorial axis. The white was probably the colour reflected by the brightest parts of the inner and outer rings. I saw that the dark band was divided near the limbs of the planet by fine bright lines, one near each limb, but I could not with certainty trace the division right across the dark band. The bright division could not, according to Trouvelot, represent a view of *Saturn* seen through the Cassini gap; it was probably the bright outer rim of the inner ring. Two dusky belts south

and one north, the poles dusky. At 5^h 50^m the equatorial bright belt seemed rather brighter than the equally broad bright space on the other side of the dark band, whose breadth was the same also. At 5^h 58^m A.M. I perceived that the north edge of the dark band had a deep orange tint, and there seemed to be a short semi-elliptic bright segment cut out of this orange border at about its middle. The orange tint is that of *Saturn* seen through the crape ring. Both ansæ continued to be easily visible till 6^h 5^m A.M.; they became faint at 6^h 9^m, and flashed out occasionally at 6^h 13^m, as did also *Rhea* and *Tethys*. The preceding ansa was the more easily caught sight of at 6^h 20^m A.M., when *Titan* was only just perceptible, a light haze now coming up. At about 6^h 0^m A.M. I had perceived bright projections, one on each ansa; that on the preceding ansa, about halfway, was possibly due to the atmosphere of the ring, that on the following ansa, near its E. end, may have been *Mimas*.

November 3, 5^h 25^m A.M.—The blue ansa west of *Saturn* seen through light cloud, *Tethys* E., *Titan* W. At 5^h 28^m very good definition (with power 180), *Mimas, Rhea, Dione* closely followed the E. end of the ring, the blue ansa east being very plainly seen also. (*Enceladus* too close to *Saturn* to be detected.)

At 5^h 38^m both ansæ visible. At 5^h 48^m both ansæ alternately visible through thin passing cloud. At 5^h 53^m I noticed the colour of the equatorial belt to be yellow, the rest of *Saturn* pale white, except where dark band and dusky belt S. and N. cross it, the N. belt very faint. The dark band is again seen to be orange tinted on its N. edge. *Dione* and *Rhea* could be seen at 5^h 59^m; but at 6^h 11^m, in spite of the light haze, both ansæ were more easily visible than those two satellites. The preceding ansa, the south dusky belt, dark band, and bright equatorial belt remained visible up to 6^h 31^m, when *Titan* could be only glimpsed through the haze.

From these circumstances, I am confident that if the blue ansæ had been visible to any telescope at all comparable with that in my charge on the morning of October 31, I should have seen them. It has been already stated that they came into view immediately on the morning of November 2. I conclude, therefore, that the plane of *Saturn's* rings probably passed through the Sun's centre on November 1, at about 6 A.M., or possibly one hour, or two hours at most, earlier. From the heliocentric longitude ($172° 6' 17''\cdot0$) and heliocentric latitude ($2° 8' 38''\cdot3$ N.) of *Saturn*, October 31, 18^h G.M.T. (astronomical time), and with an inclination $28° 10' 11''\cdot4$ of the ring plane to the ecliptic for $1891\frac{5}{8}$, which is derived from Bessel's formula (with the values of δn, δi and m, stated by Professor J. A. C. Oudemans to be the correct solution of Bessel's own equations (in *Monthly Notices of the Royal Astronomical Society*, December, 1888, page 57), I infer that the node of *Saturn's* rings on the ecliptic, when the ring-plane passed

through the Sun, was in longitude 168° 5′ 45″·7.* I may mention that Professor Oudemans has kindly informed me, by letter dated November 6, that with his 9½-inch refractor, at Utrecht, he had a clear view of *Saturn* on the Friday morning and saw no ring, that Saturday (October 31) was overcast, and on Sunday morning he once, for a moment only, at 5^h 10^m A.M. (G.M.T), fancied he saw the ring through passing clouds, but Monday again was overcast, and he did not see the ansæ until Tuesday morning. His observations confirm the inference I had reported to him as derivable from my own views of *Saturn* on the mornings of Saturday, October 31, and Monday, November 2.

Murston Rectory, Sittingbourne:
1891 *November* 9.

Comparative Photographic Spectra of the Sun and the Metals. Series I. and II. By F. McClean, M.A.

I wish to lay before the Society two series of photographic spectra, in which the spectra of the Sun and of the fifteen metals enumerated are mounted in parallel sections, in order to facilitate their comparison and the identification of their lines. The spectra extend from wave-length 3,800 to wave-length 5,750 tenth metres, or from above (H) to near (D).

Series I. contains spectra of the Sun, iron, platinum, iridium, osmium, palladium, rhodium, ruthenium, gold and silver. The last eight constitute the platinum group of metals.

Series II. contains the spectra of the Sun, iron, manganese, cobalt, nickel, chromium, aluminium and copper. These seven metals constitute the iron-copper group.

Each series consists of six sections, corresponding to six sections of Ångstrom's chart.

The broad lines and bands which run uniformly across all the metallic spectra are due to the air. This spectrum is always present when the induction spark is taken between metal electrodes in the air. Its lines and bands are coarser, relatively to the other lines, than in the original negative. This is due to their prominence and consequent over-exposure in the negative. A special series of photographs are requisite to obtain the air spectrum relatively at its best, but as it is shown here it will bear comparison with the existing maps of it.

Before the true spectra of the metals can be arrived at, it is necessary to further eliminate the lines due to various impurities in the specimens of the metals employed as electrodes. Iron

* Bessel's equations, corrected as above, give 168° 4′ 16″·1 as the longitude of the node for 1891⅝. The difference seems probably attributable more to the unknown nutation of the ring, caused by all the satellites, than to the small disturbing precessional influence exercised by the Sun and *Iapetus*.

appears in the spectrum of aluminium, and to a less degree in other spectra. Calcium is almost universally present, and becomes especially prominent throughout Section I. Its principal lines run with varying strength across nearly every spectrum, and coincide with marked groups of lines in the solar spectrum. The calcium spectrum appears most strongly in osmium and cobalt. The principal barium lines are also present in osmium, and its complete spectrum is no doubt present in Section I.

The beautiful fluting of lines in Section IV. of the aluminium spectrum, is attributed by Thalén to the oxide of aluminium formed in the aureole of the induction spark. The similar well-defined but less-marked fluting which occurs in many of the spectra in Section I. must be due to one of the constituents of the air. It cannot be due to calcium, as it is prominent in metals where calcium is absent.

The spectra of iridium, ruthenium, and rhodium, are, I believe, practically new work, and so I think are some of the other spectra, to the extent of Section I. and part of Section II.

The specimens of the metals of the platinum group which have been employed, were all obtained from Messrs. Johnson and Mathey, and were nominally pure.

The specimens of the metals of the iron group and most of the other specimens prepared for the further prosecution of the work have been obtained from Messrs. Hopkin and Williams. Some are nominally pure, but others, including aluminium, nickel, and cobalt, do not seem procurable in a pure state.

The identification of iron lines in the solar spectrum is, of course, evident. The identification of chromium, manganese, cobalt and nickel with weaker lines, can readily be made. It is impossible, however, to obtain any complete results from these two series of photographs alone. Photographs of the spectra of all the common oxidisable metals, and particularly of calcium, barium, magnesium and titanium, are first required; also duplicates of the present photographs are necessary in order to make direct comparisons between the separate spectra. The mounted photographs are being reproduced by the Direct Photo-Engraving Company. Specimens of four of the prints will be found along with the originals. The white lines unfortunately become a little coarser in the process.

1891 *November* 10.

Mean Areas and Heliographic Latitudes of Sun-spots in the year 1890, deduced from Photographs taken at Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. l. p. 378, and are deduced from the measurements of solar photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ, for each synodic rotation of the Sun in 1890; and Table II. gives the same particulars for the entire year. The areas are given in two forms: First, projected areas, that is to say, as seen and measured on the photographs, these being expressed in millionths of the Sun's apparent disc; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere. Table III. exhibits for each rotation in 1890 the mean daily area of whole spots, and the mean heliographic latitude of the spotted area, for spots north and for spots south of the equator, together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Projected. Whole Spots.	Projected. Faculæ.	Corrected for Foreshortening. Umbræ.	Corrected for Foreshortening. Whole Spots.	Corrected for Foreshortening. Faculæ.
	d							
485	1890 Jan. 1·19	28	8·4	47·8	180	7·2	45·3	213
486	Jan. 28·54	27	0·8	3·3	54·0	0·5	2·2	71·8
487	Feb. 24·87	26	16·9	94·1	229	14·1	83·7	264
488	Mar. 24·19	28	0·8	8·7	45·9	0·5	5·5	52·1
489	Apr. 20·47	27	4·6	33·3	81·1	3·0	23·0	93·5
490	May 17·70	27	3·7	22·8	130	2·9	17·1	152
491	June 13·90	27	13·3	78·2	140	11·0	68·4	155
492	July 11·10	26	24·9	150	238	19·2	115	296
493	Aug. 7·31	28	59·0	394	142	36·3	241	156
494	Sept. 3·56	26	26·3	176	489	22·6	160	536
495	Sept. 30·83	27	47·7	316	604	36·2	247	598
496	Oct. 28·12	28	18·1	104	626	16·1	96·9	658
497	Nov. 24·43	26	60·9	344	520	38·4	224	644

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected. Umbræ.	Projected. Whole Spots.	Faculæ.	Corrected for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
1890	361	21·3	133	273	15·5	99·4	304

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (Observations of Solar Spots, made at Redhill, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
	d			°		°	°	°
485	1890 Jan. 1·19	28	34·4	22·54	10·9	10·72	+14·58	19·71
486	Jan. 28·54	27	2·2	24·47	0·0	...	+24·47	24·47
487	Feb. 24·87	26	82·9	32·76	0·8	30·43	+32·15	32·74
488	Mar. 24·19	28	2·6	25·55	3·0	26·28	− 2·21	25·94
489	Apr. 20·47	27	8·3	24·37	14·7	28·02	− 9·04	26·70
490	May 17·70	27	2·0	20·97	15·1	26·79	−21·30	26·12
491	June 13·90	27	0·0	...	68·4	23·58	−23·58	23·58
492	July 11·10	26	32·0	18·28	83·0	11·55	− 3·22	13·39
493	Aug. 7·31	28	231	21·20	9·3	19·67	+19·66	21·17
494	Sept. 3·56	26	88·8	21·39	70·9	21·33	+ 2·43	21·37
495	Sept. 30·83	27	4·0	20·47	243	23·08	−22·37	23·03
496	Oct. 28·12	28	27·4	19·49	69·5	23·94	−11·67	22·68
497	Nov. 24·43	26	190	20·10	33·8	27·81	+12·87	21·26

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
1890	361	53·1	22°·20	46·3	21°·75	+1°·73	21°·99

The above tables, when compared with those given on pp. 378 and 379 in volume l., show clearly that the Sun-spot minimum is already past, a conclusion which is abundantly con-

firmed by the rapid increase in the numbers and areas of spots and faculæ seen during the present year, 1891. The tendency for spots to form in high latitudes, which was noticed towards the end of 1889, continued throughout 1890, the mean distance from the equator of all spots in 1890 being 21°·99, as compared with 11°·61 in 1889 and 7°·39 in 1888. This difference is due chiefly to the nearly total disappearance of spots from the immediate neighbourhood of the equator in 1890, for only one considerable group during the entire year, that of July 22—August 1 had a lower latitude than 18°; at the same time the spots of the new series, that is to say, of the high-latitude zones, north or south, were much more numerous than in 1889 and maintained as great a distance from the equator.

The northern hemisphere showed a slight preponderance over the southern as to spot activity in 1890, for the first time since 1881.

Observations of Wolf's Periodical Comet (b 1891) made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the East, or Sheepshanks, Equatoreal, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination.

Magnifying power about 200 on October 2, 3, 4, and 55 on October 9, 12, and 14.

Greenwich Mean Solar Time.	Observer.	☄−✱ R.A.	Corr. for Parallax.	Corr. for Refraction.	☄−✱ N.P.D.	Corr. for Parallax.	Corr. for Refraction.	No. of Comps.	Apparent R.A.	Tabular R.A.	Apparent N.P.D.	Tabular N.P.D.	Comp. Star.
d h m s		m s	s	s	′ ″	″	″		h m s	h m s	°	° ′	
Oct. 2 11 8 41	T.	+0 37·0	−0·4	0·0	−13 23·2	−7·3	−0·3	1		4 28 13		76 41·7	*a*
11 17 13	„	+2 49·9	−0·4	0·0	−10 39·0	−7·3	−0·1	6	4 28 16·4	4 28 13	76 42 11·6	76 41·7	*b*
11 23 38	„	+2 1·3	−0·4	0·0	− 7 7·2	−7·2	0·0	4		4 28 14		76 41·8	*c*
3 11 30 36	A.C.	−0 13·6	−0·4	0·0	+ 2 25·7	−7·3	0·0	4		4 29 20		77 11·7	*d*
11 33 56	„	+1 39·5	−0·4	0·0	+13 31·0	−7·2	+0·2	3	4 29 20·5	4 29 20	77 11 44·2	77 11·8	*e*
4 10 41 47	H.	−1 41·9	−0·4	0·0	− 1 20·5	−7·6	0·0	6	4 30 23·8	4 30 21	77 40 50·1	77 40·7	*f*
10 53 33	„	−0 57·6	−0·4	0·0	− 2 44·9	−7·5	0·0	3		4 30 21		77 40·9	*g*
9 11 27 34	T.	+5 19·0	−0·4	0·0	+13 40·2	−7·6	+0·3	2	4 34 57·0	4 34 56	80 16 32·8	80 16·2	*h*
11 27 34	„	+5 14·5	−0·4	0·0	+13 3·3	−7·6	+0·3	2	4 34 56·1	4 34 56	80 16 28·8	80 16·2	*k*
12 10 42 46	H.	+1 48·0	−0·4	0·0	− 3 55·1	−8·0	−0·1	6	4 37 7·2	4 37 3	81 51 32·0	81 51·2	*l*
10 51 16	„	+1 26·1	−0·4	0·0	− 0 35·3	−8·0	0·0	2		4 37 4		81 51·4	*m*
11 6 8	„	−0 34·1	−0·4	0·0	− 3 29·8	−7·9	0·0	2		4 37 4		81 51·7	*n*
14 11 10 35	L.	+1 17·3	−0·4	0·0	+14 30·6	−8·0	+0·4	2	4 38 19·6	4 38 16	82 56 58·9	82 56·6	*o*
11 10 35	„	+0 33·6	−0·4	0·0	+12 55·7	−8·0	+0·3	2		4 38 16		82 56·6	*p*

Assumed Mean Places of Comparison Stars.

	Star's Name.	R.A. 1891·0. h m s	N.P.D. 1891·0. ° ′ ″	Authority.
a	Anonymous			
b	W.B. (1) IV. 482	4 25 24·63	76 53 10·9	Weisse's Bessel (1)
c	B.D. + 13°, 694	4 26 13	76 51	Bonn Observations, vol. iii.
d	Anonymous			
e	W.B. (1) IV. 531	4 27 39·27	76 58 50·6	Weisse's Bessel (1), with proper motion, − 0″·27 in N.P.D., deduced from comparison with Armagh Catalogue I. and Sj.
f	90 Tauri	4 32 3·86	77 42 31·1	Greenwich 10-Year Catalogue, 1880.
g	B.D. + 12°, 616	4 31 20	77 44	Bonn Observations, vol. iii.
h	Armagh, I. 980	4 29 36·01	80 3 13·7	Armagh Catalogue, 1840; R.A. from Weisse's Bessel (1)
k	88 Tauri	4 29 39·67	80 3 46·6	Armagh Catalogue, 1840
l	W.B. (1) IV. 725	4 35 17·12	81 55 49·3	Weisse's Bessel (1)
m	B.D. + 8°, 737	4 35 40	81 54	Bonn Observations, vol. iii.
n	B.D. + 7°, 700	4 37 43	81 56	Bonn Observations, vol. iii.
o	W.B. (1) IV. 760	4 37 0·28	82 42 50·9	Weisse's Bessel (1)
p	B.D. + 7°, 701	4 37 42	82 44	Bonn Observations, vol. iii.

Star *e* was observed with the Transit Circle on November 7, and a preliminary reduction gives R.A. 1891·0 $4^h\ 27^m\ 39^s{\cdot}83$, N.P.D. 1891·0 76° 58′ 41″·5. The observations are corrected for refraction and parallax; in computing the latter log Δ has been taken from Berberich's Ephemeris, the values used being: October 2, 9·9310, October 3, 9·9287, October 4, 9·9268, October 9, 9·9177, October 12, 9·9127, October 14, 9·9097. The tabular places given are also interpolated from Berberich's Ephemeris.

The initials T., L., H., A.C., are those of Mr. Thackeray, Mr. Lewis, Mr. Hollis, and Mr. Crommelin respectively.

On the Orbit of Spitaler's Comet (VII. 1890).
By Lieut.-General Tennant, C.I.E., R.E., F.R.S.

In No. 3010 of the *Ast. Nach.*, Professor Spitaler expressed an opinion that at its last passage through its descending node this comet passed so near *Jupiter* that its orbit must have been entirely changed. Since then Dr. Hind has made a communication to the Academy of Sciences at Paris, pointing out that the best orbit of the comet did not justify this conclusion.

Soon after seeing Professor Spitaler's remark, I collected such information as was available about the comet, and resolved to examine the question. As an American orbit differed very sensibly from that used by Spitaler, I computed a fresh one from the Vienna Observations of 1890 November 16 and December 13, and that made at the Lick Observatory on 1891 January 12.

From these I deduced the following elements:—

Perihelion passage 1890 October 26·11874 = $2^h\ 56^m\ 59^s$ G.M.T.

$$\left.\begin{aligned}\pi &= 58^\circ\ 15'\ 31''\!\cdot\!23\\ \Omega &= 45\ \ 08\ \ 01\cdot32\\ \iota &= 12\ \ 51\ \ 27\cdot69\end{aligned}\right\}\text{Equinox of } 1891\cdot0$$

$$\phi = 28^\circ\ 12'\ 45''\!\cdot\!58$$

$$\left.\begin{aligned}\mu &= 554\cdot2197\\ \log a &= 0\cdot5375498\end{aligned}\right\}\text{Period} = 2338^d\cdot46 = 6\cdot4022 \text{ years}$$

Comparing these with the whole of the observations I could find, the result was a very general agreement, showing that the accuracy was far greater than usual in comet observations. The observation at Lick on 1890 December 11 was found to have the time too late by two hours, and this correction was kindly verified by the observer, Mr. Barnard. The whole number of observations was very small, but I deduced the following errors of the Ephemeris founded on the above elements:—

Paris M.T.	$\Delta\alpha \cos\delta$	$\Delta\delta$
1890 Nov. 16·644	$+1''\!\cdot\!1$	$-0''\!\cdot\!7$
Dec. 6·247	$-1\cdot5$	$-0\cdot3$
Dec. 10·558	$-1\cdot1$	$-3\cdot2$
Jan. 8·074	$-4\cdot5$	$+2\cdot2$
Jan. 12·131	$+0\cdot1$	$-1\cdot0$

On forming equations of condition for correcting the elements referred to the equator, it was evident, as might have been expected, that a change of π could be almost entirely compensated by one of the time of Perihelion Passage; and so, that a change in the Major Axis would be compensated by one in the eccentricity. After making the equations homologous, I adopted the following plan:—

For r and x the unknowns, which are multiples of the corrections required to μ and ϕ, I substituted r' and x', such that $r' = r + x$ and $x' = r - x$; similarly for y and z multiples of the corrections to τ and π' were substituted $y' = y + z$ and $z' = y - z$.

Of course the coefficients of x' and z' were too small to give any trustworthy determinations; but, after forming the normal equations, it was found that when the unknowns, which were multiples of the corrections to the inclination and node, were eliminated the coefficients of x' and y' were both very small, and these quantities also were indeterminate. Four then of the elements are subject to very large corrections.

Eventually I found the following corrections:—

$$\Delta\iota = +1''\cdot91 + 378\cdot5d\mu - 1\cdot434d\phi - 32923d\tau + 4\cdot151d\pi'$$
$$\Delta\Omega = +7\cdot10 + 2081\cdot4d\mu - 1\cdot424d\phi - 23416d\tau + 14\cdot192d\pi',$$

and π requires the small correction

$$\Delta\pi = -0''\cdot53 - 142\cdot3d\mu + 0\cdot174d\phi + 1844d\tau - 0\cdot107d\pi',$$

where π' is the longitude of Perihelion referred to the equator.

By substituting the numerical parts of the values determined for the two retained unknowns in the equations of condition, I found

Sum of errors before correction	in Æ =		−6''·1	in Dec.	−3''·0
„ after	„	„	+0·2	„	0·0
Sum of squares before	„	„	24·93	„	16·66
„ after	„	„	15·79	„	12·94

The corrected elements then are subject to the uncertainty resulting from corrections to π' and the other three elements.

$$\left.\begin{array}{l} \pi = 58^\circ\ 13'\ 50''\cdot69 \\ \Omega = 45\ \ 08\ \ 08\cdot42 \\ \iota = 12\ \ 51\ \ 29\cdot60 \end{array}\right\}\text{Equinox of } 1891\cdot0,$$

the others being unchanged.

With these elements there can be no very near approach to *Jupiter* at the time supposed by Dr. Spitaler. Nor is it readily conceivable that the observations will admit such changes as would make a near approach possible. It is remarkable that, where the conditions have been so unfavourable, successive computers have arrived at orbits so near each other as those published.

Measures of Planetary Nebulæ with the 36-inch Equatoreal of the Lick Observatory. By S. W. Burnham, M.A.

During the progress of my regular double star work with the 36-inch equatoreal, I have occasionally examined some of the more interesting nebulæ, and incidentally a few of the Herschel planetary nebulæ. It occurred to me that objects of the latter class would be specially suitable for careful micrometrical measures for the purpose of determining, now or hereafter, whether they have any proper motion in space. I assumed that some of the many observers of nebulæ had already done this for at least the brighter nebulæ of this class, or those where the central stars were bright enough to bring them within the reach of ordinary instruments. I was surprised to find, upon looking over many of the works of the leading observers, that very little, almost nothing, had been done in this field; and I determined, therefore, to measure all the objects of this class when it could be done without seriously interfering with the regular micrometer work on double stars. In the selection of objects classed as planetary nebulæ, I have relied, of course, upon Dreyer's General Catalogue. After an examination of a few of the prominent examples, it is not difficult to say whether or not a doubtful object belongs to the planetary class, since it is entirely a matter of appearance in the telescope, and has nothing to do with the nature of the nebulæ as shown by the spectroscope or otherwise. A central star is usually found in these nebulæ. This is so generally the case as to suggest that as the criterion for classification. Some of these stars are very faint, and can only be seen with a large aperture, and, in a few instances, the large object-glass furnishes none too much light for their accurate measurement with the micrometer. As will be seen from the observations, I have found but two or three nebulæ, which could be otherwise described as of the planetary class, where the central star is wanting. From the wide range of these stars in magnitude, it is fair to infer that the missing stars might be seen with a telescope of still greater light-power. One of these is very far south, and too low in this latitude for any very faint star.

I have also examined Nos. 934, 2440, 2452, 4107, 5144, and 6210 of Dreyer's General Catalogue, and found them more or less lacking in the characteristics of planetary nebulæ. They belong to a much larger and less interesting class of objects, which would be briefly described as small circular patches of nebulosity. Many of the more recently discovered nebulæ, though very much fainter, and usually smaller, are similar in a general way. I have also looked at a number of the so-called "stellar" nebulæ, discovered by Pickering, Swift, and others. These are all, so far as I have examined them, very small, bright, round nebulæ, which in a small instrument would resemble stars slightly out of focus, but do not appear to come within the planetary class.

Various powers have been used in studying these central stars, and particularly the brighter ones. In no instance has any one of these stars presented under any power any peculiar appearance. So far as it can be determined in this way, they all appear to be true stars, differing in no sense from the comparison stars. Many of the nights on which these measures were made were of the best quality, and any nebulous or other unusual appearance should have been apparent if it really exists.

I have not attempted to give any detailed description of these objects, in the first place because it was foreign to the special purpose in view, and secondly because verbal descriptions, like most of the drawings, have at this time little scientific value, and particularly so far as the question of change or motion is concerned. Certainly no one would predicate any change upon evidence of this kind. Skilled observers, even with instruments of about the same power, differ greatly, and it is impossible to eliminate the real from the imaginary. I have, therefore, limited my observations to actual measures with the micrometer, the accuracy of which can be tested at any time.

I think there can be no doubt that these central stars are in some way associated with the nebulæ themselves, and that any change in the positions of these stars will be accompanied by a corresponding drift in space of the nebulæ. Of the thousands of nebulæ now known, these examples in the planetary class, with a few exceptions possibly among very minute nebulæ, are the only ones where any proper motion could be detected within any reasonable time. For this reason there is no reliable evidence yet of the change in position of any nebula in the heavens. There is no apparent reason why the nebulæ should not be distributed in space in the same manner as the stars, and with the same varying distances from our system. If this is so, the nebulæ should be drifting in space with proper motions analogous to those of the stars. A re-measurement of these objects a few years from now will detect at once even a small annual variation. Some of them can be measured with much smaller instruments than the one now used. In some instances the comparison star is very faint, but I have endeavoured to select the best star, taking the magnitude and distance both into account. Should any relative change be shown hereafter, it will be easy to determine to which of the stars it belongs.

In the observations which follow, I have used Dreyer's number and place. In nearly every instance the measures were made with a power of 350, the higher eye-pieces having too small a field for many of the distances. The measures are made by double distances, except in the single instance noted, and of course with a bright-wire illumination, which interferes in no way with the visibility of the faintest object.

Barnard.

$$\left.\begin{array}{l}\text{R.A. } 3^h\ 38^m\ 34^s \\ \text{Decl.} + 34°\ 37'\cdot 6\end{array}\right\}$$

This planetary nebula was discovered by Barnard in December last while observing Zona's Comet (*Ast. Nach.* 3017). It is a fine object in the telescope, and perfectly planetary in general appearance. On one occasion I suspected a central star or a very small nucleus, but this has not been verified. It is slightly elliptical in a north and south direction. A rough setting of the wires on two nights gave, with a power of 1000, 10″·0 as the diameter of the nebula in this direction. Barnard re-measured the diameter December 10, 1890, and obtained 8″·5.

The nearest catalogue star is *D.M.* +34°, 732, called 9·0 *m* by Argelander:

Nebula and D.M. +34°, 732.

1891·689	119°·6	204″·50 . . .	8
·692	119·5	203·74 . . .	8·3
1891·69	119·5	204·12	

These are single distances. The measures give for the difference in R.A. 14s·4, and for the difference in Decl. 100″·7. In December, 1890, Barnard observed these differences directly, using the 12-inch refractor, and obtained 14s·4 and 102″·0 for the corresponding values.

I have also measured the nearest of the two faint stars referred to in *Ast. Nach.* 3017, from the centre of the nebula, with the following result:—

Nebula and 13 *m. Star Preceding.*

1891·689	288°·4	21″·79 . . .	13
·692	287·8	21·78 . . .	13
1891·69	288·1	21·78	

The other star, 14 *m*, is 33″ from the nebula, in the direction of 347°. The magnitude of the nebula was estimated by Barnard as 10 *m*. It is easily found from the sketch of the field given in *Ast. Nach.* 3017.

Applying the differences obtained above to the D.M. place of the comparison star, we have for the nebula (1860) the place given above.

No. 1501.

R.A. $3^h\ 54^m\ 59^s$
Decl. $+60°\ 32'$

	°	″		
1890·775	193·8	90·97	12·5 . . .	12·7
1890·777	193·8	91·03	13·5 . . .	13·7
1890·77	193·8	91·00	13·0 . . .	13·2

This is one of the Herschel planetary nebulæ. The central star is brighter than the nearest available comparison star.

There are two observations of these stars with the Rosse reflector, the second of which is probably by Copeland:

	°	″
1867·961	195·7	91·5
1873·870	192·9	89·9

No. 1514.

R.A. $4^h\ 0^m\ 30^s$
Decl. $+30°\ 24'$

	°	″		
1891·657	357·4	69·94	8·6 . . .	14
·689	357·9	70·11	8·6 . . .	14
·692	357·2	70·18	8·6 . . .	14
1891·68	357·5	70·08	8·6 . . .	14

The small star used for comparison is in, or near, the edge of the nebula. The diameter of the nebula is about 126″. The small star does not appear to have been noticed before. Herschel speaks of a "faint star following," and in another observation, "star suspected *n. p.*," but no distance is given. In the drawing by Rosse (*Phil. Trans.* 1861) a small star is shown in the direction of 60° or 70°, and distant about one diameter of the nebula from its edge. This nebula is not described as planetary in Dreyer. Mr. Barnard called my attention to it as probably belonging to the planetary class; and it certainly possesses the general characteristics. The surface, however, is not uniform, but broken and mottled.

No. 1535.

R.A. $4^h\ 7^m\ 44^s$
Decl. $-13°\ 6'$

	°	″		
1890·760	257·3	119·42	11·5 . . .	12
1890·775	257·0	120·21	11·0 . . .	11·5
1890·785	257·1	119·69	11 . . .	12
1890·77	257·1	119·77	11·2 . . .	11·8

Besides the central star, there are other fainter stars within the nebula. The most prominent of these is near the northern edge of the circular disc. I have measured this from the central star as follows:—

	°	″		
1890·760	323·1	16·47	. . .	15
1890·775	324·6	16·26	. . .	14·5
1890·785	324·7	15·79	. . .	14
1890·77	324·1	16·17	. . .	14·5

This nebula is ♅ IV. 26. It has been drawn by D'Arrest (*Instrumentum Magnum Æquatoreum*, 1861); and by Lassell (*Memoirs R.A.S.*, vols. xxiii. and xxxvi.). The 14·5 *m.* star does not seem to have been seen by these observers.

There are two measures of the distant star by Copeland at Parsonstown.

	°	″		
1873·003	256·7	122·9	. . .	14^m
1873·041	256·7	121·2	. . .	13^m

No. 2022.

R.A $5^h\ 34^m\ 26^s$
Decl. $+9°\ 1'$

	°	″			
1890·802	192·6	95·60	14·5	. . .	13·5
1890·840	192·2	95·34	15	. . .	14
1890·82	192·4	95·47	14·7	. . .	13·7

There is no star in the middle of this nebula, but there is a very faint one on the *s.p.* edge, and that is the one measured. The nearest outside star is *n.f.*, and about one diameter of the nebula distant. With reference to the nebulous disc Lassell says: "Some bright patches or nodules seem to exist in it, but nothing more can be made out." There are drawings by D'Arrest and Lassell in the volumes last cited, and also by Secchi (*Mem. Coll. Rom.* 1852–5).

No. 2392.

R.A. $7^h\ 20^m\ 53^s$
Decl. $+21°12'$

	°	″			
1890·879	3·0	99·62	9·0	. . .	8·2
1890·882	2·9	99·74	8·7	. . .	8·2
1890·88	3·0	99·68	8·9	. . .	8·2

One of the most beautiful objects of the kind in the heavens. The central star is round and sharp with all powers. A measure of the diameter of the bright inner disc in the direction of the outside comparison star gave 19″·0; and for the diameter of the whole disc in the same direction 44″·7 (1890·88). There are drawings of this nebula by Lassell (*Mems. R.A.S.* xxiii. and xxxvi.); D'Arrest (*Observations of Nebulæ*, 1867); Rosse (*Phil. Trans.* 1850); and Secchi (*Mem. Coll. Rom.* 1852–55). Lassell speaks of the comparison star as being nebulous. I did not notice any peculiarity in the appearance of this star. Schönfeld (in 1862·19) made the difference in R.A. $0^s·20$ and in Decl. 100″·4. These stars have been measured directly as follows:—

1853·20	2°·6	100″·12	OΣ	4n
1864·98	2·4	100·16	Knott	4n
1873·70	2·9	98·0	Copeland	3n

No. 2438.

R.A. 7^h 35^m 26^s
Decl.. −14° 25′

Central Star and Star sf.

1890·939	127°·1	49″·88	12 . . .	11·5
1891·151	127·6	49·56	12 . . .	10·7
1891·04	127·3	49·72	12 . . .	11·1

These stars were measured at Parsonstown.

1873·006	128°·6	48″·7	. . .	Copeland 1n
1876·123	129·6	50·0	16 . . .	Dreyer 1n

Central Star and Star in Nebula.

1890·939	209°·0	15″·10 . . .	14·5
1891·151	210·7	15·27 . . .	13·5
1891·04	209·8	15·18 . . .	14·0

The last measures connect the central star with a faint star in the *s.p.* side of the ring. This is probably the star shown in Rosse's drawing, and must be the one shown in Lassell's drawing, although the position-angle is erroneous if the drawing is to be looked at in the usual way. The outside diameter of the nebula

is 63″·9. There are drawings by Rosse (*Phil. Trans.* 1850); Lassell (*Mems. R.A.S.* xxiii.); and Secchi (*Mem. Coll. Rom.* 1852–5). Copeland has a single measure of the last-named star.

1873·063	210°·8	17″·4	13–14 . . .	16

No. 2452.

R.A. $7^h\ 41^m\ 47^s$ }
Decl. −27° 0′ }

Not planetary. There are two nuclei, giving it a sort of dumb-bell appearance.

No. 3242.

R.A. $10^h\ 18^m\ 2^s$ }
Decl. −17° 56′ }

	°	″		
1891·241	173·1	155·11	12 . . .	10·5
·244	173·0	155·47	11 . . .	10·5
·246	173·2	155·98	11 . . .	10·5
1891·24	173·1	155·52	11·3 . . .	10·5

I have made the following measures of this interesting object:—

Direction of the longer axis of the Ellipse	324°·8
Longer diameter of the whole Ellipse ...	42″·4
Shorter „ „ „ ...	38·3
Longer diameter of inside ring	23·2
Shorter „ „ „	17·0

This nebula has been drawn by Herschel (*Cape Observations*); Lassell (*Mems. R.A.S.* xxiii. and xxxvi.); Secchi (*Mem. Coll. Rom.* 1852–5); and Rosse (*Trans. R. Dublin Soc. II.*). There is a single observation of these stars by Searle (Annals Harvard Obs. xiii.) giving 172°·5 : 154″·64 (1868·06). The comparison star is called 13 *m*. There is also a single measure of Copeland, 173°·9 : 155″·2 (1874·18).

No. 3587.

R.A. 11h 6m 40s }
Decl. +55° 47′ }

1891·239	25°·3	156″·15	13·5 . . .	10
·241	24·5	156·49	14·5 . . .	10·5
·244	24·6	156·79	14·5 . . .	11
1891·24	24·8	156·48	14·2 . . .	10·5

This has been drawn by Rosse (*Phil. Trans.* 1833, 1850).

No. 4107.

R.A. 11h 59m 35s }
Decl. +11° 23′ }

Not planetary, but it is brighter in the middle, and extended in the direction of 115°. In Dreyer it is described as having a star 10–11 *m.*, south following. There is nothing in that place, but there is a star of that magnitude north preceding.

No. 6369.

R. A. 17h 20m 49s }
Decl. −23° 38′ }

1891·594	58°·8	90″·52	14 . . .	13·5
·597	46·7	90·30	15 . . .	13·8
1891·59	57·7	90·41	14·5 . . .	13·7

This is an annular nebula, and very much like the well-known example in *Lyra*, except in brightness. The longer axis is in the direction of 33°, and the extreme diameter on that line is 31″. Herschel has a drawing in Cape Observations. I am not aware of the central star having been seen before.

No. 6543.

R.A. 17h 58m 36s }
Decl. +66° 38′ }

1891·392	292°·3	163″·34		
·395	292·4	163·14	9·5 . . .	9·0
·397	292·4	163·18	9·7 . . .	8·8
·416	292·4	163·28	9·5 . . .	8·7
1891·40	292·4	163·24	9·6 . . .	8·8

This is the well-known planetary nebula in *Draco*. It has been more frequently observed than any other object of this class with the exception of the ring nebula in *Lyra*. The comparison star is D.M. +66°, 1065. The only direct measures of these stars which I have found are two single observations with the Rosse reflector by Dreyer as follows:—

1873·709	290°·1	161″·6
1873·711	291·2	162·8

In 1871–2 Brunnow used the same stars in an attempt to measure the parallax of the nebula, but measured the difference of declination only (*Dunsink Observations III.*). From a large number of measures he found this difference to be 62″·90. Later, Bredichin, in a similar work, used the same stars and method of observation (*Annals Obs. Moscow III.*), but I have not seen this volume and do not know what result he obtained. Schönfeld (1861·64) obtained 63″·4; and Schultz in 1865, as a mean of five rather discordant measures, 63″·0. These different results apparently indicate a movement on the part of one or the other of the stars, or that at least some of the observations are of very doubtful value; but the important fact must be considered that the central star was not really seen at all by most of the observers, and that the measures were made from the estimated centre of the nebula. Schultz used the "geometrical centre" of the nebula, and Schönfeld evidently did not see the star. At Parsonstown, where the direct measures were made, it was noted "no certain indication of a central star"; and therefore these observations, like those giving the difference in declination, cannot be compared with the late measures for the purpose of determining whether or not there has been any relative change. The Dunsink measures, however, seem to be on a different footing in this respect, for Brunnow says that the nebula "has in the centre a well-defined point resembling a star of the eleventh magnitude. I have compared this point in declination with a star to the north of the tenth magnitude," etc. Evidently the star was not very conspicuous with the Dunsink Equatoreal, or it would not have been referred to as a "point resembling a star," but it was undoubtedly well enough seen to make a definite point for placing the wires.

O. Struve from a single night found 293°·0 : 164″·40 (1848·73), and by two measures of the difference in declination in 1841 and 1848, 63″·5 and 64″·1.

The difference of the declination of the two stars, computed from my measures of the position-angle and distance, is 62″·20. This is 0″·7 less than Brunnow's value, and should be much too large for the ordinary errors of observation, particularly in measures of this kind where the telescope is stationary, and the bisection of the stars is so easily and certainly made. After

learning of this difference I determined to see whether the value derived from the angle and distance would be confirmed by observing the difference of declination with the same instrument used in the direct measures. By this method I obtained the following:—

1891·652	Dif. Decl. = 62″·42
·655	62·31
·666	62·25
·671	62·34
1891·66	62·33

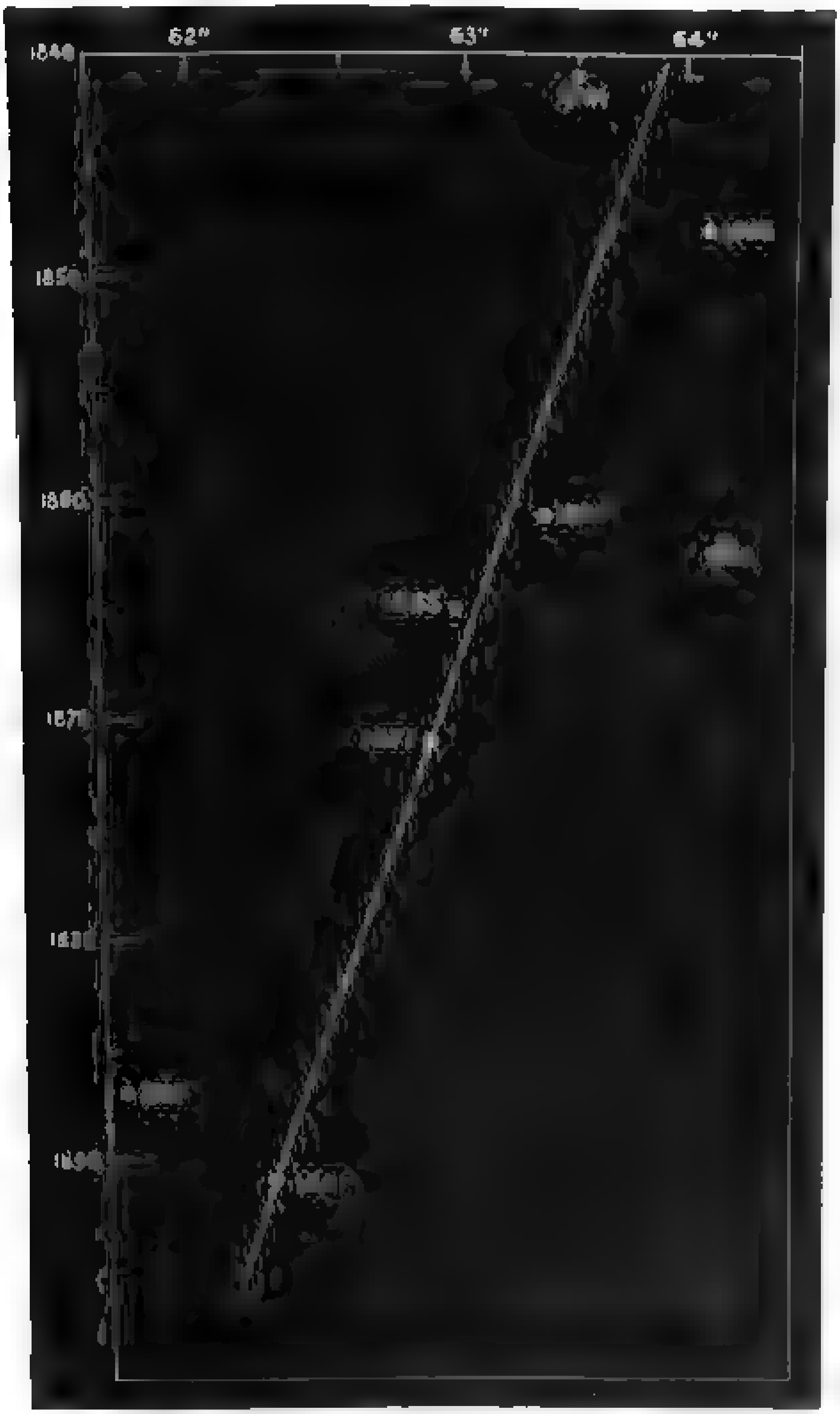
The difference between this result and that derived from the first series of measures is only 0″·13, a quantity which is insensible in direct measures of that distance, and within the limits of error in careful observations.

The various results found for the difference in the declination of these two stars, arranged in chronological order, are as follows:—

1841	Dif. Decl. 63″·5	O Σ.
1848	64·1	O Σ.
1861	63·4	Schönfeld.
1862	64·2	Argelander.
1865	63·0	Schultz.
1871	62·90	Brünnow.
1887	61·6	Engelhardt.
1891	62·26	β.

All of these measures appear to have been made with the micrometer with the exception of Argelander's, which were with the meridian circle (*Bonn Observations*, VI.).

These observations are laid off to scale on the accompanying diagram. It is apparent that there is a slow change in the declination of one of these stars, and that the difference is steadily decreasing. An examination of these positions, and omitting for this purpose those of 1862 and 1887, shows that the annual change in declination amounts to 0″·033. It is probably impossible to determine at this time to which star, if only one, this motion belongs.



Dreyer 6543.
Observed differences of Declination.

There are drawings of this nebula by Vogel (*Bothkamp Observations*, IV.), and by Holden and Schaeberle (*Mon. Not.* xlviii. 390).

No. 6563.

R.A. $18^h\ 2^m\ 48^s$
Decl. $-33°\ 53'$

This nebula is fairly planetary in appearance, and there seem to be some faint stars in it, but the central star is wanting. No drawings cited in Dreyer.

No. 6572.

R.A. $18^h\ 5^m\ 18^s$
Decl. $+6°\ 50'$

1891·575	77°·0	33″·02	10·5 . . .	14·5
·578	75·5	32·82	11·0 . . .	15·5
·597	76·6	33·08	11·0 . . .	15
1891·58	76·4	32·97	10·8 . . .	15

This is one of the brightest of the planetary nebulæ. It is sometimes spoken of as Σ 6, which is an unfortunate as well as an improper method of referring to the list of nebulæ observed by Struve, since the symbol Σ preceding a numeral has been universally used to designate the double stars comprised in the great catalogue of double stars, *Mensuræ Micrometricæ.*

There are drawings of this nebula by Secchi (*Mem. Coll. Rom.* 1852–5), and by Vogel (*Pub. Potsdam. Obs.* IV.). I have not seen these illustrations.

No. 6720.

R.A. $18^h\ 48^m\ 23^s$
Decl. $+32°\ 51'$

1891·326	88°·2	61″·64	15·5 . . .	12
·416	87·8	61·44	15·5 . . .	13·5
·419	86·5	61·56	15·5 . . .	12
·518	88·4	62·28	15 . . .	13
·559	88·0	61·56	15·5 . . .	11·5
1891·45	87·8	61·69	15·4 . . .	12·4

This is the well-known annular nebula in *Lyra.* All the measures were made under very favourable conditions, and the central star well seen. When the seeing was the best, and perfect for all practical purposes, the ring and the darker interior were carefully examined with various powers, but without detecting any other stellar point. In various places there are minute areas of slightly brighter nebulosity, but none of them appear to be stars. There are many drawings of this nebula. The

comparison star in the foregoing measures is the familiar one near the following edge of the nebula.

No. 6781.

R.A. $19^h\ 11^m\ 38^s$
Decl. $+6°\ 17'$

1891·562	72°·1	49″·22	15 . . .	12
·575	74·5	49·50	15 . . .	13
1891·57	73·3	49·36	15 . . .	12·5

The primary star is not central, but is north of the middle. Drawings have been made by Lamont and Lassell.

No. 6818.

R.A. $19^h\ 36^m\ 4^s$
Decl. $-14°\ 29'$

This seems to present a true planetary appearance, but there is no central star. There appear to be two or three slight con densations of nebulous matter, which at first glance might be taken for faint stars, but I do not think they are real stellar points. There are drawings by Rosse, Lamont, D'Arrest, and Secchi.

No. 6826.

R.A. $19^h\ 41^m\ 2^s$
Decl. $+50°\ 11'·2$

1891·747	194°·1	96″·15	9 . . .	10
·750	194·4	96·17	8·7 . . .	9
1891·75	194·2	96·16	8·8 . . .	9·5

This beautiful object is almost an exact duplicate of the planetary nebula in *Draco*. It is slightly elliptical, with the longer axis in the direction of 295°. A setting of the wires gave for the longer diameter 26″·6, and for the shorter 24″·3. There are a number of stars nearer than the one measured. The nearest, about 14 *m*, is 27″·0 from the central star, in the direction of 283°·1. Drawings have been made by Herschel and Secchi.

Engelhardt (*Observations Astron. II.*) by three measures made the difference of declination between the two stars, 93″·5 (1887·79). Computed from my angle and distance it is 93″·2.

No. 6891.

R.A. 20^h 8^m 32^s } Decl. $+12°$ $19'$

Central star and *p* star *a*.

1890·785	242°·3	42″·67	11	. . . 12
·840	242·5	43·20	12	. . . 13
1890·81	242·4	42·93	11·5	. . . 12·5

Central star and *p* star *b*.

1890·802	289°·0	57″·15	12·5	. . . 11·5
·840	289·4	57·40	12	. . . 10·5
1890·82	289·2	57·27	12·2	. . . 11·0

In making the second measure a different comparison star was used, and therefore both were subsequently measured. This nebula was discovered by Copeland.

No. 6894.

R.A. 20^h 10^m 45^s } Decl. $+30°$ $8'$

1891·594	186°·7	119″·65	15	. . . 11·5
·610	185·3	119·92	15	. . . 10·8
1891·60	186·0	119·78	15	. . . 11·1

Considerably darker in the middle, and apparently belongs to the annular class. The faint star within is not central, but is near the preceding side. There are many stars nearer the nebula than the 11 *m* comparison star. This nebula has been figured by Rosse (*Phil. Trans.* 1833). (*Trans. R. Dublin Soc. II.*)

No. 6905.

R.A. 20^h 16^m 9^s } Decl. $+19°$ $40'$

1891·594	358°·0	46″·76	14	. . . 10
·610	357·2	46·61	14	. . . 10
1891·60	357·6	46·68	14	. . . 10

A measure of the diameter of this nebula in the direction of the 10 *m* star gave 39″·1. There are many drawings by the principal observers. Searle gives difference of declination between nebula and star (central star not mentioned) as 46″·33 (1867·65). (*Annals Harvard Coll. Obs. XIII.*)

No. 7009.

R.A. $20^h\ 56^m\ 33^s$
Decl. $-11°\ 55'$

	°	″			
1890·709	343·3	96·45	12·5	. . .	13
·725	343·7	96·55	11·5	. . .	12
·777	343·4	96·13	12	. . .	13
1890·74	343·5	96·38	12	. . .	12·7

There are many drawings of this object, sometimes called the "*Saturn* nebula," references to which will be found in Dreyer.

The following single measures are from the Rosse observations:—

	°	″
1873·655	343·3	99·0
1874·695	343·3	101·2

No. 7026.

R.A. $21^h\ 1^m\ 33^s$
Decl. $+47°\ 17'$

	°	″
1891·562	271·7	6·21
·575	272·6	6·40
·578	274·5	6·74
1891·57	272·9	6·45

This nebula was discovered by me in 1873 with the 6-inch refractor, with which it was also seen double or elongated. One of the nuclei is brighter than the other. The measures given above are of the angle and distance between these nuclei. They are not stars, but small enough for fairly accurate bisection. This object does not properly belong to the planetary class of nebulæ. Some rough measures were made a few years ago which differ much from the results given here, but it is not probable that any change has occurred in the nebula.

No. 7027.

R.A. $21^h\ 1^m\ 48^s$
Decl. $+41°\ 40'$

	°
1891·575	131·0
·578	135·1

Discovered by Webb. It has two nuclei, the following one of which is fairly well defined, but the brighter is too large and

diffused for reliable measures of distance. There is nothing planetary about the appearance of this nebula. The nearest star is 15 *m*, and is about 14″ from the bright condensation, in the direction of 96°.

No. 7208.

R.A. 21^h 59^m 25^s }
Decl. $-29°$ $44'$ }

This is a faint circular nebula, but not specially planetary in appearance. Herschel's description is, "almost planetary."

No. 7354.

R.A. 22^h 35^m 8^s }
Decl. $+60°$ $33'$ }

There seems to be a faint condensation near the margin of the nebula on the preceding side, but there is no central star; otherwise it presents the true planetary appearance. Dreyer has no reference to any drawings.

No. 7662.

R.A. 23^h 19^m 11^s }
Decl. $+41°$ $46'$ }

1890·782	62°·4	51″·82	15 . . .	13
·785	63·4	51·87	15 . . .	13
1890·78	62·9	51·84	15 . . .	13

A number of drawings have been made of this nebula, references to which will be found in Dreyer. Searle (*Annals Harvard Coll. Obs.* XIII.) measured the outer star from the centre of the nebula (the central star not seen), and from two observations gives 62°·7 : 52″·14 (1866·80). O. Struve from four nights found 61°·3 : 51″·85 (1847·86). He states that the central star, which has been noted with the Rosse reflector, was not seen. (*Mélanges Math. et Ast.* III.)

Lick Observatory:
1891 *October* 14.

Corrections and Additions to the Observations of Sirius.
By S. W. Burnham, M.A.

In my paper on *Sirius* (*Monthly Notices*, April 1891), in the references to the various authorities on page 384 the name Eastman (*A.N.* 1526, 2678) should be changed to Engelmann, and Eastman should be added in another line with a reference to *Monthly Notices*, xxxviii. 360, and *A.N.* 1680. In the former are found his measures of 1878, given in the list of observations of that year on page 382 of my paper. The angle and distance of the companion are derived from observations with the Meridian Circle on three nights. The measures by this observer for 1867 are taken from the *Washington Observations* of that year, and not from *A.N.* 1680, where a slightly different value is given.

In the *Memoirs of the Royal Astronomical Society*, xxxvi. 38, observations of Lassell and Marth, there are some measures of the angle of the companion which are not included in the list I have given. It is not clear by whom the measures were really made. The mean result of three nights for the position-angle is 76°·8 (1865·10).

I am indebted to M. Bigourdan, of the Observatory of Paris, for having called my attention to the omission of the following measures:—

1872·21	66°·6	10″·69	Börgen	3*n*
1873·23	70·0	9·80	Börgen	1*n*
1873·23	66·3	10·42	Bruhns	1*n*
1880·18	46·7	9·92	Bigourdan	6–4*n*
1881·14	44·3	10·62	Bigourdan	5–3*n*
1882·13	42·4	9·76	Bigourdan	4–3*n*
1883·19	39·9	9·10	Bigourdan	2–1*n*
1884·17	35·3	8·79	Bigourdan	3–1*n*

The first three are found in *Pub. Universitats-Sternwarte zu Leipzig*, Heft, 1882. The observations of Bigourdan are printed in the *Annales de l'Observatoire de Paris* (Observations of 1883). I have never seen these volumes, and until this time was not aware of any such measures having been made. These are valuable observations, and should be added to the list I have given.

Mount Hamilton:
Oct. 19.

A Note on some Photometric Experiments connected with the Application of the Law of limiting Apertures to small Object-glasses. By Edmund J. Spitta.

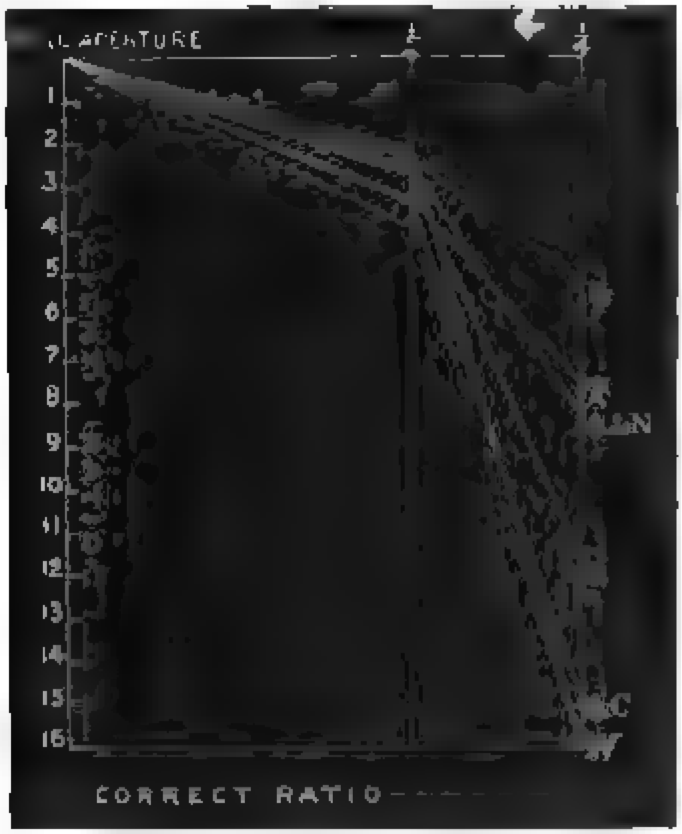
Whilst carrying out some experiments connected with the paper read before the Society in November last, certain doubtful and equivocal results immediately followed the application of a diaphragm to the telescope in use, and these were of so pronounced a character that the use of such means for reducing the intensity of the luminant had to be abandoned. It was known a doubt had always existed as to whether the intensity of a point of light viewed at the focus of a refracting telescope would, when photometrically tested, be found to vary as the square of the linear aperture of the object-glass; in other words, whether it was scientifically accurate or strictly philosophical, seeing its compound nature and its different mode of manufacture, to apply to an object-glass what is generally known as the law of limiting apertures.

Having, therefore, tested photometrically the different zones of this object-glass, and proved that the law (anyhow, with the telescope in question) was *not* applicable, it was thought it would be of interest, seeing the subject had not received any extended investigation, to photometrically test objectives of different makers' manufacture, both English and foreign. Although at present I have only been able to examine telescopes of small aperture, the results furnish me with figures so different, although all in the same direction, that it has been suggested it would be of interest to publish this preliminary note.

In the accompanying table the first column gives the distinguishing name of the object-glass examined; the second and third its aperture and focal length; whereas the fourth and last set forth the actual ratios photometrically obtained, when the aperture was lineally reduced to one-half and one-quarter respectively.

Table of Ratios photometrically obtained.

		inches.	inches.		
I.	Alvan Clark	6·5	93	.........$1 : \frac{1}{3·35}$	......$1 : \frac{1}{14·84}$
II.	Tulley	3·1875	46·5	.........$1 : \frac{1}{3·3}$	......$1 : \frac{1}{7·5}$
III.	Clerkenwell	2·625	42	.........$1 : \frac{1}{2·63}$	......$1 : \frac{1}{11·70}$
IV.	Watson	2·8125	41	.........$1 : \frac{1}{2·11}$	......$1 : \frac{1}{15·91}$
V.	Grubb	2·875	40·8	.........$1 : \frac{1}{2·31}$	......$1 : \frac{1}{5·07}$
VI.	A. and N.	2·375	24·75	.........$1 : \frac{1}{2·47}$	......$1 : \frac{1}{8·23}$



On examination both the table and the diagram show that in all cases, except perhaps that of the object-glass by Alvan Clark, the rays passing through the outer zones do not contribute to the intensity of the focal image as much as theoretically they should. It would seem, too, that focal length is not a factor of importance, as the resulting ratios, although all in the same direction appear to be different in each case, even when the dimensions are nearly similar. But I submit, however, that a solution of the difficulty very possibly lies in the aplanatisation of the respective glasses. With any of the modifications of the zonal treatment it is not difficult to understand that in some instances perfection of definition at the focus has not arisen from a combination of those rays of the spectrum selected by the optician to be united from *all parts* of the object-glass, but has been effected, unconsciously it may be in some cases, by pushing the focus of the rays from the outer zones aside, so as to be finally lost or cut off by suitable diaphragms. This is much the same as when the artist in achromatising neglects the rays from the extreme ends of the spectrum, or permits their focus to be at some place other than that occupied by the visual focus. If the object-glasses I examined were made somewhat in this way, it is easy to perceive how it came about that the application of a large diaphragm, *i.e.* one of large aperture placed between them and the source of light, did not appropriately reduce the brilliancy of the image at the focus. In other words, it would be evident the reason the large diaphragms had not affected the resulting ratios in a manner they should was due to the fact that they were placed over

portions of each object-glass, which only contributed in a slight degree to the intensity of the image at the focus.

This suggestion, which I venture to submit for the consideration of those better versed in practical optics, was forced upon me by the peculiar phenomena displayed by one of the telescopes I purposely examined photometrically with diverging light (which, of course, very much exaggerated the true state of things). I was surprised to find, when all the internal diaphragms were removed, that the rays from the outermost zone had a focus very sensibly different in length to those from the neighbouring and central ones. Yet the object-glass, when examined as set in its tube, had given much satisfaction in defining powers, going in and out of focus with considerable rapidity. Of course, the use of truly parallel rays, such as are received from a star, would, and indeed were, on trial, actually found to materially alter this state of things, but it was the fact itself that seemed of some importance, as it appeared to me to point in what direction it might be possible to find a solution capable of explaining the different figures that resulted when the law of limiting apertures was applied to the several object-glasses I had examined. It was thought, too, that this explanation would offer a suggestion how it came about that Dr. V. L. Charlier, in *Publications of the Astronomical Society of the Pacific*, No. 17, had actually seemed to prove that the use of diaphragms did not in his telescope control the photographic intensity of a point of light according to theoretical considerations.

Again, too, if such reasoning be true, it is not difficult to see why half the linear aperture of a large telescope has so often been noticed to reveal fainter stars than the full aperture of another of the same linear dimensions.

Another experiment was tried which is of sufficient negative interest to merit being recorded. It was suggested that the peculiar figures of the table perhaps resulted for the most part from differences in the angles of incidence at which the cylindrical beam received from a star impinged upon different zones of the curved anterior surface of each objective respectively. Accordingly, the Clerkenwell object-glass was reversed in its cell so that the posterior surface of its flint glass, which was sensibly flat, should receive the rays from the source of light; but it was found that the ratios did not differ more than by a reasonable observational error from those given in the table, which were obtained with the objective in its normal position.

It is, perhaps, worth mentioning, that on studying the literature of the subject, I find I am not alone in obtaining the peculiar figures of the table, for Dr. Müller, of Potsdam,* working with a Zöllner photometer, reduced his aperture in such

* *Publicationen des Astrophysikalischen Observatoriums zu Potsdam—Photometrische Untersuchungen.*

ratios that the computed values of the logarithms of brilliancy of a star were :—

1·0742
0·7959
0·4437

but the observed ratios were :—

0·3695
0·3439
0·2687

He remarks, therefore, that the rays coming through the outer parts of his object-glass had very little effect on the brilliancy of the image; and it was only when the diameter had been diminished, say about one half, that the observed and computed ratios had a tendency to agree. But, he adds, that with a larger telescope of 135 mm. aperture—that is, about five and a quarter inches—the difference between the observed and computed ratios became almost nil. This corresponds very approximately with my own experience.

Wolff,* too, after conducting several experiments with an object-glass of 37·4 mm. diameter, comes to much the same conclusion, although, as a matter of fact, I am not able to find that he carried his investigation any further with telescopes of larger proportions.

As it has been pointed out to me, the value of the figures in the table would be increased by giving some of the actual wedge-readings; I select the two sets from which the mean values of the performance of the Grubb objective have been obtained, because they were taken on two different nights. When these are reduced it has been found that the resulting ratios do not differ *inter se* by a quantity much greater than ·1 magnitude.

	Full ap.	½ ap	¼ ap.	Full ap.	½ ap.	¼ ap.
	3·19	1·40	0·33	4·30	2·29	0·65
	3·23	1·75	0·32	3·75	2·32	0·82
	3·23	1·60	0·29	3·63	2·47	0·80
	3·20	1·48	0·33	3·85	2·47	0·75
	3·23	1·53	0·5	3·73	2·30	0·64
			0·39		2·40	
M.	3·21	1·55	0·36	3·85	2·37	0·73

It will be noticed that on two occasions six observations were accidentally taken instead of five.

1891 *November*.

* *Photometrische Beobachtungen an Fixsternen*, 1878, pages 20–22.

On New Forms of Levels. By H. H. Turner, M.A., B.Sc.

The striding or hanging level in its usual form has so often given erroneous results that it is perhaps unnecessary to quote instances in detail. The errors chiefly arise from want of uniformity in the scale; and it is no doubt a serious difficulty to obtain a tube of glass of sufficiently slight and sufficiently uniform curvature to make the scale even approximately the same in different portions of its length. Moreover, the usual method of dealing with an erroneous scale—careful determination of the division errors by calibration—is not here completely applicable; for the length of the bubble changes with temperature, and the division errors for one temperature are not the same as for another. Experiments made in 1889 on some level bubbles used in the determination of the Paris-Greenwich longitude showed that this effect of changes of temperature was perhaps not so great as might be expected, and that a table might be formed at a mean temperature for correcting the mean of the readings of the ends of the bubble, which would apply without serious errors at all moderate temperatures. But this process cannot be called satisfactory when great accuracy is desired.

It occurred to me recently that we could be independent of this unsatisfactory scale if the small screw for adjustment of zero of the bubble were made a fine micrometer screw. This screw would then be turned until the bubble took up a definite position on the scale, and the micrometer head read; on reversing the bubble the screw would again be turned until the same position was reached, and the head again read. The difference of readings of the screw is then twice the level error, and the scale is no longer used except as a series of fiducial marks, any one of which may be selected according to convenience. Messrs. Troughton & Simms readily undertook to make an experimental level-bubble on this plan, and the only practical difficulty they encountered was in providing a fine enough screw. They ultimately decided to obtain the requisite sensitiveness by making the screw act on a system of levers instead of one lever only. A striding-level with micrometer screw was received from them on 1891 July 7, and found to work satisfactorily. Three others were therefore made for use with the portable transits in the proposed Montreal-Greenwich longitude operations, which it was hoped to commence this year, but which were finally deferred until 1892. The use of these levels in the meantime with one or other of the portable transits * has suggested the following remarks:—

* The Transit Circle object-glass was removed by Messrs. Troughton & Simms for repolishing on 1891 August 10, and the transits were in constant use for time determination at the Royal Observatory from that date until October 5.

I. The addition of the screw does not, of course, diminish but increases the time required for an observation of level and the probable error of a single observation, for there are now two things to observe instead of one, and two sources of error. It is the systematic and not the accidental errors that are diminished. In practice, I think, it will be found best to make each observation of level consist of four distinct operations, somewhat as follows :—

Reading of Screw.	Direction of Motion.	Readings of Bubble. E.	W.
r		d	d
9·500	Incr.	15·2	69·6
9·500	Decr.	15·6	69·9
10·000	Incr.	69·0	14·7
10·130	Decr.	71·2	17·0

The first pair of readings is taken without disturbing the instrument, except to turn the screw head in opposite directions to the reading 9·500. The slight difference of readings of the bubble will be referred to presently (IV.). The level is then reversed and another pair taken. To avoid holding the screw too long with the fingers, and thus possibly warming one end of the level, it is set quickly to a reading estimated to be approximately that which will bring the bubble to its old position; and the error of this estimation, which becomes obvious on taking the readings of the bubble, is corrected in the second setting of the screw by arranging that the mean of the second pair of bubble readings shall be nearly the same as the mean of the first pair. If the relation between the value of a revolution of the screw and that of one division of the scale is even approximately known, this coincidence of the mean readings can be readily secured with considerable accuracy. The present example was chosen as a rather unfavourable instance, the difference of the means ($42^{d}\cdot98$ and $42^{d}\cdot58$) being $0^{d}\cdot4$, and for this a correction must be applied, depending on the value of the bubble-scale; but it is obvious that no sensible error in level will be introduced by a moderately erroneous scale value for such a small quantity.

II. The additional labour during the operations is to some extent compensated by a saving in preliminary determination of constants. The evaluation of the screw is much less laborious than the calibration of the scale, for the want of uniformity in different parts is much smaller, and, in fact, should be insensible if the screw is properly made by a good maker; whereas no one has yet apparently succeeded in making uniform bubble-scales. Moreover, the evaluation of some screw, viz. that of the level-prover, is also necessary for the ordinary form of level-bubble; and consequently the requisite labour is to some extent common to both cases. The new form of level is, in fact, simply a combination of level and prover in one instrument.

III. It may be remarked that there is a definite advantage gained in the possibility of selecting the part of the scale to be used. Not only can certain accidental errors be eliminated by using different parts of the scale at different times during the observations, but the more defective parts of the scale may be avoided. Such are either:—

(*a*) Parts where the value of a division changes most rapidly. If the scale of an ordinary level be calibrated, and the value of one division at different parts of the scale be plotted on paper in the ordinary way, the resulting curve generally has one or more points of inflexion. At these points the rate of change in the value of one division is a maximum, and the accidental error of an observation is therefore large. A rough calibration of the scale for the detection of such points is therefore advisable even when the micrometer screw is added, so that readings of the bubble at such points may be avoided; and on the other hand, of course, the best points to select for readings should be chosen, which are those where the curve indicates a uniform scale.

(*b*) Parts where there is something in the nature of a frictional obstruction in the glass. Without further comment I may perhaps refer to a note by Mr. G. C. Comstock in the *Sidereal Messenger* for 1891 June, p. 299. Referring to a remark of Prof. Safford's, that "In some cases impurities in the ether dissolve particles of the glass, loosen other particles, and make the bubble sluggish by adhesion," Mr. Comstock continues: "It is interesting to note that this peculiarity of levels has been made the subject of special study by one of the scientific bureaux of the German Government," and gives the following account of the results attained:—

"In the course of time secretions are formed upon the inner surface of the glass and render the level unfit for use. It has been ascertained by experiment that these are due to the action of the water, traces of which are usually found in the ether with which the levels are filled. Since it is exceedingly difficult to fill a level with ether which is entirely free from water, a kind of glass which is but little affected by the action of water should be chosen in the construction of the level. A method for testing this quality of the glass by means of a colour reaction has been devised, and may easily be applied even by an unskilled person. Let a glass tube be filled with a solution of water and ether containing also a little eosin. After the solution has stood for some time in the tube the glass will assume a ruddy tint, and the greater the action of the water upon the glass the more pronounced will this tint become. By the decomposition of the glass a certain quantity of alkali is liberated and is transformed by the eosin into a coloured salt.

"The conclusion of the whole matter reached by the author of the report is, that a level tube before it is filled should always be subjected to a special treatment, consisting in removing from

the ground-glass surfaces their alkaline components by means of an acid."

IV. It may be questioned whether a certain amount of sluggishness is not discernible in all bubbles. In a sensitive level the bubble approaches the position of equilibrium gradually, and may take several minutes of time to reach it. Readings taken before the end of this time will be in excess or defect according as the bubble is moving in the negative or positive direction. The screw provides a means of giving a gentle motion in opposite directions, and thus sensibly eliminating any errors which may be introduced by the necessity for reading without wasting too much time. An example was given in remark I., and is fairly representative, the difference of $0^{d}\cdot35$ between the readings of the bubble when brought to the same reading ($9^{d}\cdot500$) of the screw, but in opposite directions, being about the mean of such observed differences for the four levels used at Greenwich. Of course with the ordinary form of level such a motion may be given by a gentle tilt with the hand, though this is more liable to be jerky; and it is to be feared that the tendency is rather to set the level down indifferently and trust to the errors balancing in the long run, though it is quite conceivable that a habit might be acquired of setting down one end always first, in which case a systematic error would be introduced.

V. Level bubbles are sometimes permanently attached to instruments (as in the altazimuth used at the Royal Observatory, Greenwich), and are only reversed in the reversal of the instrument. In such cases, changes of temperature are apt to alter the zero of the bubbles so that they run off the scale for some positions of the instrument, unless the adjusting screws are altered to correspond. The addition of a micrometer screw to such levels would not indeed remove the necessity for altering the adjusting screw, but would rather make it a necessary part of every observation, so that the alteration would not be unexpectedly found necessary at an inconvenient time, as is sometimes the case at present when bad weather has interrupted the observations for some time.

The announcement of the above paper suggested a new form of level to Dr. A. A. Common, which he has asked me to describe briefly in an additional note. He proposes to combine some of the advantages of the nadir-observation and the striding-level determination and avoid some of their disadvantages, in a new instrument which can be readily placed on the pivots in various positions of the latter, reversed end for end, or removed, just as the striding-level, and the fundamental principle of which shall be reflexion from mercury as in the nadir-observation, instead of the motion of an air-bubble. The cylindrical tube joining the uprights of this instrument is a telescope tube, a flat bar being added above or below the tube to ensure rigidity. To the object-glass is firmly attached a reflecting prism, and the

eyepiece is a Bohnenberger, with wire frame. The light from the wires passes through the object-glass and is reflected vertically downwards by the prism to a trough of mercury placed underneath the projecting face of the prism, is returned to this face of the prism and back through the telescope, forming an image of the wires in the same plane as themselves. A micrometer screw applied either to the whole telescope and prism, or to the wires alone, will give a reading for coincidence, the difference of which, from a similar reading for coincidence in the reversed position of the instrument, will be twice the level error. No instrument of this kind has yet been constructed, and it may be found necessary to modify the details; but the principle is in some ways new, and it was thought advisable to include this brief sketch of the idea in the present paper. A diagrammatic section of the proposed instrument would be somewhat as below.

B = Bohnenberger eyepiece. The illumination of the wires may be effected by the axis-lamp of the transit by an additional prism to throw this light upwards towards the reflector in B.

O = object-glass of telescope T.

P = reflecting prism.

M = Mercury trough.

L, L′ = legs to stand on pivots, as in the striding-level.

R = flat bar to strengthen the connections.

On the Conjunction of Venus and Jupiter, 1892 *February* 5–6. By A. Marth.

The close conjunction of *Venus* and *Jupiter*, predicted in the Almanacs as occurring on February 5 at 22^h Greenwich mean time, offers to observers in Australia, in Japan, and in adjacent terrestrial regions the rare chance of making the simple observations required for answering the question, What are the limits of angular distance within which such bright bodies can or cannot be separated by the naked eye? The geocentric distance between the centres of the two planets will be

		h m		h m	
within 3′	from	21 4	to	23 24	G.M.T.
„ 2	„	21 29	„	22 59	„

As the observations require no artificial means except watches or clocks for knowing the correct time, and consist merely in watching the planets after sunset and noting the times when they cease to appear separated and when they begin to appear so again, it is to be hoped that the interesting phenomenon will be duly observed by very many pairs of eyes, and that the best use will be made of the rare opportunity.

On the present occasion the planets will be $33°·6$ east of the Sun. On the last occasion, 1826 August 1, when a close conjunction of *Venus* and *Jupiter* took place in the evening, the angular distance from the Sun was $36°·2$, and Australia was again favoured, but I do not know whether any observations were got at Paramatta. Since then a close morning conjunction occurred 1859 July 20, 16^h Greenwich mean time, but the planets were only $18°·5$ west of the Sun, and no results of value were obtained.

The position-angle p and the angular distance s of the centre of the disc of *Venus* referred to that of *Jupiter* may be obtained by means of the formulæ

$$s \sin(p-P) = x = x_0 - [0·3498]\,\rho'' + [0·6771]\,\rho' \sin(G+\lambda)$$
$$s \cos(p-P) = y = y_0 - [0·6743]\,\rho'' - [0·3577]\,\rho' \sin(H+\lambda),$$

in which $x_0\ y_0$ denote the geocentric rectangular coordinates of *Venus* referred to the axes of the disc of *Jupiter*, and $x\ y$ the corresponding topocentric coordinates for a place in longitude λ east of Greenwich, the distance of which from the axis of the Earth is ρ', and from the plane of the equator ρ'' (reckoned negative for places on the south side). The logarithmic coefficients of ρ'' and ρ' are those for 22^h Greenwich and vary slightly, the values for 18^h being ·0004 smaller, and for 2^h ·0004 greater. The quantities $x_0\ y_0$, G, H have the following values:—

1892.	G.M.T. h m	x_0 "	y_0 "	G °	H °
Feb. 5	18 0	−635·19	−41·34	56·23	44·12
	20	585·21	·33	61·24	49·13
	40	535·23	·31	66·25	54·15
	19 0	−485·26	−41·29	71·26	59·16
	20	435·28	·28	76·27	64·17
	40	385·31	·26	81·28	69·19
	20 0	−335·34	−41·24	86·29	74·20
	20	285·37	·22	91·30	79·21
	40	235·40	·20	96·31	84·23
	21 0	−185·43	−41·17	101·32	89·24
	20	135·46	·15	106·33	94·25
	40	85·49	·13	111·34	99·27
	22 0	− 35·53	−41·10	116·35	104·28
	20	+ 14·44	·08	121·36	109·29
	40	64·40	·05	126·37	114·31
	23 0	+114·36	−41·02	131·38	119·32
	20	164·32	41·00	136·39	124·33
	40	214·28	40·97	141·40	129·35
Feb. 6	0 0	+264·24	−40·94	146·41	134·36
	20	314·20	·91	151·42	139·37
	40	364·15	·88	156·43	144·39
	1 0	+414·10	−40·85	161·44	149·40
	20	464·05	·82	166·45	154·41
	40	514·00	·78	171·46	159·43
	2 0	+563·94	−40·74	176·47	164·44

The values of the position-angle P of *Jupiter's* axis and of the apparent diameters of the disc may be taken from the ephemeris in vol. li. page 367. The assumed value of the diameter of *Venus* at distance 1 is 17″·552, q denotes the amount of the greatest defect of illumination, and Q its position-angle reckoned from the circle of declination, or Q−P the position-angle reckoned from the direction of the axis of *Jupiter*.

			♃'s *Diam.*			♀'s *Diam.*			
G.M.T.	h	P °	Equat. "	q "	Polar. "	"	q "	Q °	Q−P °
Feb. 5	18	334·708	34·04	0·11	31·87	13·52	2·31	68·5	93·8
6	2	·705	34·01	0·10	31·86	13·54	2·33		

The rectangular coordinates of the satellites referred to the axes of *Jupiter's* disc, and deduced from the data published in vol. li.,

are for the times when *Venus* is passing in their neighbourhood, the following :—

Sat. IV.

G.M.T. h m	x_4 ″	y_4 ″
19 0	−431·05	+3·96
20	430·38	4·01
40	429·70	4·06
20 0	−429·02	+4·11

Sat. II.

G.M.T. h m	x_2 ″	Diff. ″	y_2 ″
21 0	−127·36		+1·77
		+1·16	
10	126·20		1·83
		1·29	
20	124·91		1·89
		1·43	
30	123·48		1·95
		+1·56	
21 40	−121·92		+2·01

Sat. I.

G.M.T.	x_1 ″	y_1 ″
21 40	−64·68	−2·24
45	65·64	2·22
50	66·58	2·20
55	67·51	2·17
22 0	−68·43	−2·15

Sat. III.

G.M.T.	x_3 ″	y_3 ″
23 40	+256·73	+0·70
50	·77	0·66
0 0	·80	0·62
10	·81	0·57
0 20	+256·81	+0·53

According to these data, the geocentric conjunctions of *Venus* with the satellites and with *Jupiter* will take place at the following Greenwich mean times :—

Sat. IV.	*Sat. II.*	*Sat. I.*	♃	*Sat. III.*
h m	h m	h m	h m	h m
19 22·0	21 24·5	21 47·7	22 14·2	23 57·0

the distances being

−45″·3	−43″·1	−38″·9	−41″·1	−41″·7

As the sum of the semidiameters of the two planets at the time of nearest approach is 22″·7, the distance between the nearest limbs will be, geocentrically, only 18″·4, and their distance will be reduced by parallax for Adelaide to 14″·0, for Sydney and Windsor to 13″·9, and for Melbourne to 13″·8.

Whether the satellites can be successfully observed in daytime remains to be tested.

Col. Cooper's Observatory,
Markree, Collooney, Ireland.

Ephemerides of the Satellites of Saturn, 1891–92. By A. Marth.
(Continued.)

The adopted Zero-Meridian will pass the middle of the illuminated disc of Saturn at the following Greenwich mean times:—

1891.	h. m.	h. m.	1892.	h m.	h. m.
Dec. 22	11 56·8	22 11·1	Jan. 26	11 31·5	21 45·9
23	8 45·5	18 39·8	27	8 0·2	18 14·5
24	15 8·5	25 22·8	28	4 28·8	14 43·6
25	11 37·2	21 51·5	29	11 11·7	21 26·0
26	8 5·8	18 20·2	30	7 40·3	17 54·7
27	14 48·9	25 3·2	31	4 9·0	14 23·3
28	11 17·5	21 31·9	Feb. 1	10 51·9	21 6·2
29	7 46·2	18 0·6	2	7 20·5	17 34·8
30	14 29·2	24 43·5	3	3 49·1	14 3·4
31	10 57·9	21 12·2	4	10 32·1	20 46·4
1892. Jan. 1	7 26·6	17 40·9	5	7 0·7	17 15·0
2	14 9·5	24 23·9	6	3 29·3	13 43·6
3	10 38·2	20 52·5	7	10 12·2	20 26·5
4	7 6·9	17 21·2	8	6 40·8	16 55·1
5	13 49·9	24 4·2	9	3 9·4	13 23·7
6	10 18·5	20 32·9	10	9 52·3	20 6·7
7	6 47·2	17 1·5	11	6 21·0	16 35·3
8	13 30·2	23 44·5	12	2 49·6	13 3·9
9	9 58·8	20 13·1	13	9 32·5	19 46·8
10	6 27·5	16 41·8	14	6 1·1	16 15·4
11	13 10·4	23 24·8	15	2 29·7	12 44·0
12	9 39·1	19 53·4	16	9 12·6	19 26·9
13	6 7·7	16 22·0	17	5 41·4	15 55·5
14	12 50·7	23 5·0	18	2 9·8	12 24·1
15	9 19·3	19 33·6	19	8 52·8	19 7·1
16	5 48·0	16 2·3	20	5 21·4	15 35·7
17	12 30·9	22 45·2	21	12 4·3	22 18·6
18	8 59·6	19 13·9	22	8 32·9	18 47·2
19	5 28·2	15 42·5	23	5 1·5	15 15·8
20	12 11·1	22 45·5	24	11 44·4	21 58·7
21	8 39·8	18 54·1	25	8 13·0	18 27·3
22	8·4	15 22·7	26	4 41·6	14 55·9
23	1 51·4	22 5·7	26	11 24·6	21 38·9
24	8 20·0	18 34·3	28	7 53·2	18 7·5
25	4 48·6	15 2·9	29	4 21·8	14 36·1

The planetary longitudes of several spots, deduced from the times of their crossing the middle line of the disc, as observed by Mr. A. Stanley Williams (v. No. 3051 of the *Astron. Nachrichten*), are in the adopted system of longitudes:

1891.		G.M.T. h m	Long. °
May	12	11 50	3·1
	30	9 51	0·1
June	2	9 38	3·5
	5	9 13	0·0
	11	8 43	4·5
	14	8 19	1·4

		G.M.T. h m	Long. °
May	7	9 50	34·1
June	5	10 17	37·5
	14	9 17	35·4
	17	9 4	38·8
	20	8 39	35·2

		G.M.T. h m	Long. °
May	7	9 57	38·2
	13	9 33	46·5
June	11	10 2	50·7
	14	9 32	44·2
	17	9 16	45·8
	20	8 58	46·3
	26	8 24	48·4

		G.M.T. h m	Long. °
May	13	10 26·5	77·9
	22	9 42	85·2
	28	8 57	81·1
	31	8 37	80·4
June	11	11 0 est.	84·7
	20	10 5	85·6
	26	9 33	88·8
	29	9 11	86·9
July	2	8 40	79·8

		G.M.T. h m	Long. °
May	11	9 27	155·6
June	9	9 50	156·3
	12	9 36	159·2
	18	9 2	161·3

The longitude and latitude of the centre of the disc at the times assigned to Mr. Williams's sketches are:—

		G.M.T. h m	Long. °	Lat. °
Fig. 1	May 7	9 50	34·1	−5·5
2	May 13	9 33	46·5	−5·5
3	June 5	9 32	11·1	−5·2

and at the time of fig. 1 made at the Lick Observatory,

April 27	16^h 32^m	$112^\circ\!\cdot 2$	$-5^\circ\!\cdot 4$

the fig. being published on p. 498 of the *Journal of the British Astronomical Association*.

In the list of approximate Greenwich mean times of conjunction of the satellites with the end points of the equatorial diameter of the ball and with those of the ring, the letters α β γ δ denote the position of the satellites when they are in conjunction with the end points of the equator in the order "north following, south following, south preceding, and north preceding," and ϵ ζ η θ the corresponding positions as regards the end points of the ring. "Ecl. D." and "Ecl. R." denote the disappearance and reappearance of the satellite or the beginning and ending of an

eclipse, "Sh." the axis of its shadow-cone crossing or being near the central meridian of the planet's disc. It is to be understood that the times given are only intended for approximate guidance. At the conjunctions of *Titan* with the centre the coordinates of the satellite ought to be most carefully measured.

1891.	G.M.T. h	
Dec. 22	13·5	Titan ζ
	15·0	Titan Sh.
	16·3	En. ζ
	17·4	Titan β
	18·4	Mi. ζ
	20·3	Titan inf. ☌ with centre 10″·6 s.
	22·4	Di. ζ
	22·6	En. η
	23·2	Titan γ
23	0·3	Mi. η
	0·6	Di. β
	1·1	Te. ζ
	1·5	Di. Sh.
	15·1	En. ε
	17·0	Mi. ζ
	22·9	Mi. η
	23·7	Te. θ
24	1·1	Te. Ecl. D.
	1·2	En. ζ
	12·4	Rh. γ
	12·8	Di. α
	15·0	Rh. η
	15·0	Di. ε
	15·6	Mi. ζ
	17·6	En. θ
	21·5	Mi. η
	22·4	Te. ζ
	23·9	En. ε
25	0·4	Te. β
	1·3	Te. Sh.
	14·2	Mi. ζ
	16·1	Di. ζ
	16·4	En. η
	18·3	Di. β
	19·2	Di. Sh.
	20·1	Mi. η
	21·0	Te. θ
	21·6	Di. γ
	22·4	Te. Ecl. D.
	23·8	Di. η
26	1·5	Mi. θ
	1·9	Te. α
	12·2	Rh. θ
	12·8	Mi. ζ
	13·2	Rh. Ecl. D.
	18·6	Rh. α
	18·8	Mi. η
	18·9	En. ζ
	19·7	Te. ζ

1891.	G.M.T. h	
Dec. 26	21·2	Rh. ε
	21·7	Te. β
	22·6	Te. Sh.
27	0·2	Mi. θ
	0·6	Te. γ
	1·0	Di. θ
	1·3	En. η
	2·2	Di. Ecl. D.
	17·4	Mi. η
	17·7	En. ε
	18·3	Te. ζ
	19·7	Te. Ecl. D.
	22·8	Mi. θ
	23·2	Te. α
28	1·2	Te. ε
	12·0	Di. β
	12·8	Di. Sh.
	15·3	Di. γ
	16·0	Mi. η
	17·0	Te. ζ
	17·5	Di. η
	18·4	Rh. ζ
	19·0	Te. β
	19·9	Te. Sh.
	20·3	En. θ
	21·0	Rh. β
	21·4	Mi. ζ
	21·5	Rh. Sh.
	21·9	Te. γ
	23·9	Te. η
29	0·8	Rh. γ
	12·7	En. ζ
	14·6	Mi. η
	15·7	Te. θ
	17·0	Te. Ecl. D.
	18·7	Di. θ
	19·0	En. η
	19·9	Di. Ecl. D.
	20·0	Mi. θ
	20·6	Te. α
	22·6	Te. ε
30	0·1	Di. α
	13·2	Mi. η
	14·3	Te. ζ
	16·3	Te. β
	17·2	Te. Sh.
	18·4	Titan Ecl. D
	18·6	Mi. θ
	19·2	Te. γ
	21·2	Te. η
	21·6	En. ζ

1891.	G.M.T. h	
Dec. 31	0·0	Titan Ecl. R.
	0·5	Mi. ε
	0·6	Rh. θ
	1·6	Rh. Ecl. D.
	2·8	Titan sup. ☌ with centre 11″·0 n.
	11·2	Di. η
	11·8	Mi. η
	13·0	Te. θ
	14·0	En. θ
	14·3	Te. Ecl. D.
	17·2	Mi. θ
	17·9	Te. α
	19·9	Te. ε
	20·4	En. ε
	23·1	Mi. ε
1892 Jan. 1	11·6	Te. ζ
	12·3	Di. θ
	12·2	En. η
	13·6	Di. Ecl. D.
	13·6	Te. β
	14·5	Te. Sh.
	15·9	Mi. θ
	16·5	Te. γ
	17·8	Di. α
	18·5	Te. η
	20·0	Di. ε
	21·8	Mi. ε
	22·9	En. θ
2	11·6	Te. Ecl. D.
	13·3	Rh. γ
	14·5	Mi. θ
	15·2	Te. α
	15·4	En. ζ
	15·8	Rh. η
	17·2	Te. ε
	20·4	Mi. ε
	21·2	Di. ζ
	21·7	En. η
	23·4	Di. β
3	0·2	Di. Sh.
	13·1	Mi. θ
	13·8	Te. γ
	14·1	En. ε
	15·8	Te. η
	19·0	Mi. ε
4	12·5	Te. α
	13·1	Rh. θ
	13·7	Di. ε

1892.	G.M.T. h	
Jan. 4	14·1	Rh. Ecl. D.
	14·5	Te. ϵ
	16·7	En. θ
	17·6	Mi. ϵ
	19·5	Rh. α
	22·1	Rh. ϵ
	23·0	En. ϵ
	23·0	Mi. ζ
5	13·1	Te. η
	14·9	Di. ζ
	15·5	En. η
	16·2	Mi. ϵ
	17·1	Di. β
	17·9	Di. Sh.
	20·4	Di. γ
	21·6	Mi. ζ
	22·6	Di. η
6	11·8	Te. ϵ
	14·8	Mi. ϵ
	18·0	En. ζ
	19·3	Rh. ζ
	20·2	Mi. ζ
	21·8	Rh. β
	22·4	Rh. Sh.
	23·7	Di. θ
7	0·3	En. η
	1·0	Di. Ecl. D.
	1·7	Rh. γ
	12·5	Titan ζ
	13·5	Mi. ϵ
	14·1	Titan Sh.
	16·3	Titan β
	16·8	En. ϵ
	18·9	Mi. ζ
	19·2	Titan inf. ☌ with centre 11″·1 s.
	22·2	Titan γ
8	0·8	Mi. η
	2·0	Titan η
	2·2	Te. θ
	10·8	Di. β
	11·6	Di. Sh.
	12·1	Mi. ϵ
	14·0	Di. γ
	16·3	Di. η
	17·5	Mi. ζ
	19·3	En. θ
	23·4	Mi. η
9	0·8	Te. ζ
	1·5	Rh. θ
	1·7	En. ϵ
	2·6	Rh. Ecl. D.
	10·5	Rh. ϵ
	10·7	Mi. ϵ
	11·8	En. ζ
	16·1	Mi. ζ
	17·4	Di. θ
Jan. 9	18·1	En. η
	18·7	Di. Ecl. D.
	22·0	Mi. η
	22·9	Di. α
	23·5	Te. θ
10	0·9	Te. Ecl. D.
	1·1	Di. ϵ
	10·5	En. ϵ
	14·7	Mi. ζ
	20·6	Mi. η
	20·7	En. ζ
	22·1	Te. ζ
11	0·1	Te. β
	1·1	Te. Sh.
	10·2	Rh. β
	10·8	Rh. Sh.
	13·1	En. θ
	13·3	Mi. ζ
	14·1	Rh. γ
	16·7	Rh. η
	19·2	Mi. η
	19·4	En. ϵ
	20·8	Te. θ
	22·2	Te. Ecl. D.
12	11·1	Di. θ
	11·9	En. η
	11·9	Mi. ζ
	12·4	Di. Ecl. D.
	16·6	Di. α
	17·8	Mi. η
	18·8	Di. ϵ
	19·4	Te. ζ
	21·4	Te. β
	22·0	En. θ
	22·4	Te. Sh.
	23·2	Mi. θ
13	0·3	Te. γ
	13·9	Rh. θ
	14·4	En. ζ
	15·0	Rh. Ecl. D.
	16·5	Mi. η
	18·1	Te. θ
	19·5	Te. Ecl. D.
	19·9	Di. ζ
	20·3	Rh. α
	20·8	En. η
	21·9	Mi. θ
	22·1	Di. β
	22·9	Rh. ϵ
	23·0	Te. α
	23·0	Di. Sh.
14	1·0	Te. ϵ
	1·4	Di. γ
	13·2	En. ϵ
	15·1	Mi. η
	16·7	Te. ζ
	18·7	Te. β
	19·7	Te. Sh.
Jan. 14	20·5	Mi. θ
	21·6	Te. γ
	23·3	En. ζ
	23·6	Te. η
15	10·2	Di. α
	12·4	Di. ϵ
	13·7	Mi. η
	15·4	Te. θ
	15·7	En. θ
	16·8	Te. Ecl. D.
	17·7	Titan Ecl. D.
	19·1	Mi. θ
	20·1	Rh. ζ
	20·3	Te. α
	22·1	En. ϵ
	22·3	Te. ϵ
	22·7	Rh. β
	23·1	Titan Ecl. R.
	23·3	Rh. Sh.
16	1·0	Mi. ϵ
	1·5	Titan sup. ☌ w. centre 11″·1 n.
	2·5	Rh. γ
	4·5	Titan α
	12·3	Mi. η
	13·6	Di. ζ
	14·0	Te. ζ
	14·5	En. η
	15·8	Di. β
	16·0	Te. β
	16·7	Di. Sh.
	17·0	Te. Sh.
	17·7	Mi. θ
	18·9	Te. γ
	19·1	Di. γ
	20·9	Te. η
	21·3	Di. η
17	12·7	Te. θ
	14·1	Te. Ecl. D.
	16·3	Mi. θ
	17·1	En. ζ
	17·6	Te. α
	19·6	Te. ϵ
	22·2	Mi. ϵ
	22·4	Di. θ
	23·4	En. η
	23·8	Di. Ecl. D.
18	11·3	Rh. ϵ
	11·3	Te. ζ
	13·3	Te. β
	14·3	Te. Sh.
	14·9	Mi. θ
	15·8	En. ϵ
	16·2	Te. γ
	18·2	Te. η
19	10·0	Te. θ
	10·4	Di. Sh.

1892.	G.M.T. h	
Jan. 19	11·4	Te. Ecl. D.
	12·8	Di. γ
	13·5	Mi. θ
	14·9	Te. α
	15·0	Di. η
	16·9	Te. ε
	18·4	En. θ
	19·5	Mi. ε
20	10·6	Te. β
	10·8	En. ζ
	11·0	Rh. β
	11·6	Te. Sh.
	11·7	Rh. Sh.
	12·2	Mi. θ
	13·5	Te. γ
	14·9	Rh. γ
	15·5	Te. η
	16·1	Di. θ
	17·2	En. η
	17·5	Rh. η
	17·5	Di. Ecl. D.
	18·1	Mi. ε
	21·6	Di. α
	23·5	Mi. ζ
	23·8	Di. ε
21	12·2	Te. α
	14·2	Te. ε
	16·7	Mi. ε
	19·7	En. ζ
	22·1	Mi. ζ
22	0·9	Di. ζ
	10·8	Te. γ
	12·1	En. θ
	12·8	Te. η
	14·7	Rh. θ
	15·3	Mi. ε
	15·9	Rh. Ecl. D.
	18·5	En. ε
	20·7	Mi. ζ
	21·1	Rh. α
	23·7	Rh. ε
23	10·9	En. η
	11·0	Titan ζ
	11·2	Di. Ecl. D.
	11·5	Te. ε
	13·3	Titan Sh.
	13·9	Mi. ε
	14·8	Titan β
	15·3	Di. α
	17·5	Di. ε
	17·8	Titan inf. ☌ w. centre, 10″·8 s.
	19·3	Mi. ζ
	20·7	Titan γ
	21·0	En. θ
24	0·5	Titan η
	12·5	Mi. ε

1892.	G.M.T. h	
Jan. 24	13·5	En. ζ
	17·9	Mi. ζ
	18·6	Di. ζ
	19·8	En. η
	20·8	Di. β
	20.9	Rh ζ
	21·8	Di. Sh.
	23·4	Rh. β
	23·8	Mi. η
25	0·1	Di. γ
	0·2	Rh. Sh.
	1·9	Te. θ
	12·2	En. ε
	16·5	Mi. ζ
	22·3	En. ζ
	22·5	Mi. η
26	0·5	Te ζ
	11·1	Di. ε
	14·8	En. θ
	15·2	Mi. ζ
	21·1	Mi. η
	21·1	En. ε
	23·2	Te. θ
27	0·7	Te. Ecl. D.
	9·5	Rh. α
	12·0	Rh. ε
	12·3	Di. ζ
	13·6	En. η
	13·8	Mi. ζ
	14·5	Di. β
	15·5	Di. Sh.
	17·8	Di. γ
	19·7	Mi. η
	20·0	Di. η
	21·8	Te. ζ
	23·7	En. θ
	23·8	Te. β
28	0·9	Te. Sh.
	12·4	Mi. ζ
	16·1	En. ζ
	18·3	Mi. η
	20·5	Te. θ
	21·1	Di. θ
	22·0	Te. Ecl. D.
	22·4	En. η
	22·6	Di. Ecl. D.
	23·7	Mi. θ
29	1·4	Te. α
	9·2	Rh. ζ
	11·0	Mi. ζ
	11·8	Rh. β
	12·6	Rh. Sh.
	14·9	En. ε
	15·7	Rh. γ
	16·9	Mi. η
	18·2	Rh. η
	19·1	Te. ζ
	21·1	Te. β

1892.	G.M.T. h	
Jan. 29	22·2	Te. Sh.
	22·3	Mi. θ
30	0·0	Te. γ
	11·4	Di. γ
	13·6	Di. η
	15·5	Mi. η
	17·4	En. θ
	17·8	Te. θ
	19·3	Te. Ecl. D.
	20·9	Mi. θ
	22·7	Te. α
	23·8	En. ε
31	0·7	Te. ε
	14·1	Mi. η
	14·8	Di. θ
	15·4	Rh. θ
	16·2	En. η
	16·3	Di. Ecl. D.
	16·4	Te. ζ
	16·8	Rh. Ecl. D.
	17·0	Titan Ecl. D.
	17·0	Titan θ
	18·4	Te. β
	19·5	Te. Sh.
	19·5	Mi. θ
	20·3	Di. α
	21·3	Te. γ
	21·9	Rh. α
	22·1	Titan Ecl. R.
	22·5	Di. ε
	23·3	Te. η
	23·8	Titan sup. ☌ w. centre 10″·6 n.
Feb. 1	0·4	Rh ε
	12·7	Mi. η
	15·1	Te. θ
	16·6	Te. Ecl. D.
	18·1	Mi. θ
	18·7	En. ζ
	20·0	Te. α
	22·0	Te. ε
	23·6	Di. ζ
2	11·2	En. θ
	11·4	Mi. η
	13·7	Te. ζ
	15·7	Te. β
	16·8	Mi. θ
	16·8	Te. Sh.
	17·5	En. ε
	18·6	Te. γ
	20·6	Te. η
	21·6	Rh. ζ
	22·7	Mi. ε
3	0·2	Rh. β
	1·1	Rh. Sh.
	10·0	En. η
	10·0	Di. Ecl. D.

1892.	G.M.T. h	
Feb. 3	10·0	Mi. η
	12·4	Te. θ
	13·9	Te. Ecl. D.
	13·9	Di. α
	15·4	Mi. θ
	16·1	Di. ϵ
	17·3	Te. α
	19·3	Te. ϵ
	20·1	En. θ
	21·3	Mi. ϵ
4	11·0	Te. ζ
	12·5	En. ζ
	13·0	Te. β
	14·0	Mi. θ
	14·1	Te. Sh.
	15·9	Te. γ
	17·3	Di. ζ
	17·9	Te. η
	18·8	En. η
	19·5	Di. β
	19·9	Mi. ϵ
	20·5	Di. Sh.
	22·8	Di. γ
5	9·7	Te. θ
	10·2	Rh. α
	11·2	Te. Ecl. D.
	11·3	En. ϵ
	12·6	Mi. θ
	12·8	Rh. ϵ
	14·6	Te. α
	16·6	Te. ϵ
	18·5	Mi. ϵ
	21·4	En. ζ
	23·9	Mi. ζ
6	9·8	Di. ϵ
	10·3	Te. β
	11·2	Mi. θ
	11·4	Te. Sh.
	13·2	Te. γ
	13·8	En. θ
	15·2	Te. η
	17·1	Mi. ϵ
	20·1	En. ϵ
	22·5	Mi. ϵ
7	8·5	Te. Ecl. D.
	9·8	Mi. θ
	10·0	Rh. ζ
	10·9	Di. ζ
	11·9	Te. α
	12·5	Rh. β
	12·6	En. η
	13·1	Di. β
	13·5	Rh. Sh.
	13·9	Te. ϵ
	14·2	Di. Sh.
	15·7	Mi. ϵ
	16·4	Rh. γ
	16·4	Di. γ
	18·6	Di. η
Feb. 7	19·0	Rh. η
	21·1	Mi. ζ
	22·7	En. θ
8	9·1	Titan ζ
	10·5	Te. γ
	12·4	Titan Sh.
	12·5	Te. η
	12·9	Titan
	14·4	Mi. ϵ
	15·1	En. ζ
	15·9	Titan inf. ☌ w. centre 9″·9 s.
	18·8	Titan γ
	19·8	Mi. ζ
	19·8	Di. θ
	21·4	Di. Ecl. D.
	21·5	En. η
	22·6	Titan η
9	9·2	Te. α
	11·2	Te. ϵ
	13·0	Mi. ϵ
	13·9	En. ϵ
	16·1	Rh. θ
	17·8	Rh. Ecl. D.
	18·4	Mi. ζ
	22·6	Rh. α
10	9·8	Te. η
	10·1	Di. γ
	11·6	Mi. ϵ
	12·3	Di. η
	16·4	En. θ
	17·0	Mi. ζ
	22·8	En. ϵ
	22·9	Mi. η
11	13·4	Di. θ
	15·1	Di. Ecl. D.
	15·2	En. η
	15·6	Mi. ζ
	18·9	Di. α
	21·1	Di. ϵ
	21·5	Mi. η
	22·3	Rh. ζ
12	0·2	Te. ζ
	0·9	Rh. β
	14·2	Mi. ζ
	17·8	En. ζ
	20·1	Mi. η
	22·3	Di. ζ
	22·8	Te. θ
13	10·2	En. θ
	12·8	Mi. ζ
	16·5	En. ϵ
	18·7	Mi. η
	21·5	Te. ζ
	23·5	Te. β
14	10·9	Rh. α
	11·4	Mi. ζ
	12·6	Di. α
Feb. 14	13·5	Rh. ϵ
	14·8	Di. ϵ
	17·3	Mi. η
	19·1	En. θ
	20·1	Te. θ
	21·8	Te. Ecl. D.
15	11·5	En. ζ
	15·9	Di. ζ
	16·0	Mi. η
	17·9	En. η
	18·1	Di. β
	18·8	Te. ζ
	19·3	Di. Sh.
	20·8	Te. β
	21·4	Mi. θ
	21·4	Di. γ
	21·9	Te. Sh.
	23·6	Di. η
	23·7	Te. γ
16	10·3	En. ϵ
	10·7	Rh. ζ
	13·2	Rh. β
	14·4	Rh. Sh.
	14·6	Mi. η
	15·0	Titan θ
	16·4	Titan Ecl. D.
	17·1	Rh. γ
	17·4	Te. θ
	19·1	Te. Ecl. D.
	19·7	Rh. η
	20·0	Mi. θ
	20·4	En. ζ
	21·1	Titan Ecl. R.
	21·8	Titan sup. ☌ w. centre 9″·3 n.
	22·3	Te. α
17	0·3	Te. ϵ
	0·7	Titan α
	0·7	Di. θ
	8·4	Di. ϵ
	12·8	En. θ
	13·2	Mi. η
	16·1	Te. ζ
	18·1	Te. β
	18·6	Mi. θ
	19·2	En. ϵ
	19·3	Te. Sh.
	21·0	Te. γ
	23·0	Te. η
18	9·6	Di. ζ
	11·6	En. η
	11·8	Di. β
	11·8	Mi. η
	13·0	Di. Sh.
	14·7	Te. θ
	15·1	Di. γ
	16·4	Te. Ecl. D.
	16·8	Rh. θ

1892.	G.M.T. h	
Feb. 18	17·2	Mi. θ
	17·3	Di. η
	18·7	Rh. Ecl. D.
	19·6	Te. α
	21·6	Te. ε
	21·7	En. θ
	23·1	Mi. ε
	23·3	Rh. α
19	10·4	Mi. η
	13·4	Te. ζ
	14·1	En. ζ
	15·4	Te. β
	15·8	Mi. θ
	16·6	Te. Sh.
	18·3	Te. γ
	18·4	Di. θ
	20·2	Di. Ecl. D.
	20·3	Te. η
	20·5	En. η
	21·7	Mi. ε
	23·9	Di. α
20	12·0	Te. θ
	12·9	En. ε
	13·7	Te. Ecl. D.
	14·4	Mi. θ
	16·9	Te. α
	18·9	Te. ε
	20·3	Mi. ε
	23·0	Rh. ζ
	23·0	En. ζ
21	8·0	Rh. η
	8·7	Di. γ
	10·7	Te. ζ
	10·9	Di. η
	12·7	Te. β
	13·0	Mi. θ
	13·9	Te. Sh.
	15·5	En. θ
	15·6	Te. γ
	17·6	Te. η
	18·9	Mi. ε
	21·8	En. ε
22	9·3	Te. θ
	11·0	Te. Ecl. D.
	11·7	Mi. θ
	12·0	Di. θ
	13·9	Di. Ecl. D.
	14·2	Te. α
Feb. 22	14·2	En. η
	16·2	Te. ε
	17·5	Di. α
	17·6	Mi. ε
	19·7	Di. ε
23	7·2	Rh. Ecl. D.
	8·0	Te. ζ
	10·0	Te. β
	10·3	Mi. θ
	11·2	Te. Sh.
	11·6	Rh. α
	12·9	Te. γ
	14·2	Rh. ε
	14·9	Te. η
	16·2	Mi. ε
	16·8	En. ζ
	20·9	Di. ζ
	21·6	Mi. ζ
	23·1	Di. β
	23·1	En. η
24	6·9	Titan ζ
	8·4	Te. Ecl. D.
	8·9	Mi. θ
	9·2	En. θ
	10·7	Titan β
	11·5	Te. α
	11·5	Titan Sh.
	13·5	Te. ε
	13·7	Titan inf. ☌ w. centre 8″·4 s. ? Transit
	14·8	Mi. ε
	15·5	En. ε
	16·6	Titan γ
	20·2	Mi. ζ
	20·4	Titan η
25	7·6	Di. Ecl. D.
	8·0	En. η
	8·5	Te. Sh.
	10·1	Te. γ
	11·2	Di. α
	11·3	Rh. ζ
	12·1	Te. η
	13·4	Di. ε
	13·4	Mi. ε
	13·9	Rh. β
	15·3	Rh. Sh.
Feb. 25	17·8	Rh. γ
	18·1	En. θ
	18·8	Mi. ζ
	20·3	Rh. η
26	8·8	Te. α
	10·5	En. ζ
	10·8	Te. ε
	12·0	Mi. ε
	14·5	Di. ζ
	16·7	Di. β
	16·9	En. η
	17·4	Mi. ζ
	18·1	Di. Sh.
	20·0	Di. γ
	22·2	Di. η
27	7·4	Te. γ
	9·3	En. ε
	9·4	Te. η
	10·6	Mi. ε
	16·0	Mi. ζ
	17·5	Rh. θ
	19·4	En. ζ
	19·6	Rh. Ecl. D.
	21·9	Mi. η
	23·4	Di. θ
	23·9	Rh. α
28	7·0	Di. ε
	8·1	Te. ε
	9·2	Mi. ε
	11·8	En. θ
	14·6	Mi. ζ
	18·2	En. ε
	20·5	Mi. η
	23·8	Te. ζ
29	8·2	Di. ζ
	10·4	Di. β
	10·6	En. η
	11·8	Di. Sh.
	13·2	Mi. ζ
	13·7	Di. γ
	15·9	Di. η
	19·2	Mi. η
	20·7	En. θ
	22·5	Te. θ
	23·7	Rh. ζ
Mar. 1	0·3	Te. Ecl. D.

(To be continued.)

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LII. DECEMBER 11, 1891. No. 2

E. J. STONE, M.A., F.R.S., Vice-President, in the Chair.

Lord Edward Spencer Churchill, Castlemead, Windsor, was balloted for and duly elected a Fellow of the Society.

The following candidates were proposed as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Bertram Bennett, B.A., Paignton, South Devon (proposed by Edwin Dunkin);

Charles Bright, F.R.G.S., Assoc.M.Inst.C.E., M.I.E.E., Telegraph Works, Silvertown, Essex (proposed by the Earl of Crawford);

Charles Burckhalter, Assistant, Chabot Observatory, Oakland, California, 962 Chester Street, Oakland (proposed by W. M. Pierson);

Arthur Hilton Molesworth, B.A., Barrister-at-law, 15 Park Lane, W. (proposed by A. S. Herschel);

R. A. Sampson, B.A., Isaac Newton Student, St. John's College, Cambridge (proposed by A. M. W. Downing);

Charles Daulman Webb, B.A., B.Sc., Master in King's College School, 112 Adelaide Road, South Hampstead, N.W. (proposed by H. P. Hollis).

Sixty-five presents were announced as having been received since the last meeting, including, amongst others:—

Opere di Galileo, Edizione nazionale, vol. ii., presented by the Italian Government; Vienna Observatory, Annalen, Band VII., presented by the Observatory; Munich Observatory, Neue Annalen, Band II., presented by the Observatory; Paris Ob-

servatory, Catalogue et Positions observées des Étoiles, vi[h] à xii[h], presented by the Observatory; Philosophical Transactions of the Royal Society, vol. i., presented by C. L. Prince; two original negatives of the Moon, presented by the Lick Observatory; Leybourn, W., the Art of Dialling, 1682, Munster, S., Rudimenta Mathematica, 1551, and Sturmy, S., The Mariner's Magazine, 1669, presented by William Schooling.

On the Verification of the Expressions given in Delaunay's Lunar Theory by a Direct Differentiation and Substitution in the Differential Equations. By E. J. Stone, M.A., F.R.S.

In the *Monthly Notices* for November, Professor Cayley has shown by a direct differentiation of the expressions v, u, and $\frac{1}{r}$, given by Delaunay, that they satisfy the differential equations employed to the fourth order of the small fractions $\frac{n'}{n}$ or m, and for terms involving only e; and, if I understand the paper rightly, it is suggested that this method might be applied with success to test the general accuracy of Delaunay's expressions.

The general integration of the three simultaneous differential equations has been carried by Delaunay to the seventh order of the small fractions involved, whilst for certain terms, in which this degree of approximation was found insufficient, special investigations have been undertaken for the determination of the coefficients to much higher orders than the seventh; and the necessary transformations have been effected to give the expressions for v and u complete to the seventh order. But, because the inverse radius vector is ultimately multiplied by a comparatively small linear quantity, the radius of the Earth, and is compared directly with observation under the form of the Lunar Parallax, it has been thought sufficient to give the algebraical expression for $\frac{1}{r}$ only to the fifth order of small quantities; and the coordinates v, u, and $\frac{1}{r}$, as given by Delaunay, are therefore only complete to the fifth order. There would, however, be no very serious difficulty in effecting the necessary transformations and obtaining the expression for $\frac{1}{r}$ to the seventh order of small quantities, and this would render the expressions for v, u, and $\frac{1}{r}$, if accurate, complete to the seventh order. But the labour of extending these expressions generally to the high order of small quantities which has been found necessary for some terms would

be enormous; and this work is hardly likely to be undertaken and carried out. But unless the expressions for the coordinates v, u, and $\frac{1}{r}$ are complete to some definite order, p, it will, I believe, be found impossible to verify the accuracy of the work of integration in series by the inverse process of a direct differentiation of these expressions for v, u, and $\frac{1}{r}$, and the substitution of the results in the differential equations in the manner which has been successfully adopted by Professor Cayley for terms of order e. and to m^4; and if sensible errors exist in Delaunay's expressions they are far more likely to be found in terms of an order higher than the seventh, at which the general integration ends, than amongst those of a lower order.

But, even if the complete integration of the equations employed by Delaunay had been effected, it would be quite impossible to make the functions v, u, and $\frac{1}{r}$ accurately represent the geocentric coordinates of the Moon's centre of gravity by assigning any definite numerical values to the constants a e, γ, τ, g, and h, introduced in the integrations, and of the constant μ, or

$$n=\sqrt{\frac{\mu}{a^3}},$$

because the equations integrated are not the differential equations of motion. And it will be impossible to pass from the integrals v, u, and $\frac{1}{r}$ to the required integrals of the differential equations of motion,

$$v+\delta v,\ u+\delta u,\ \frac{1}{r}+\ \delta\frac{1}{r}$$

until at least the corrections which the expressions v', u', $\frac{1}{r'}$ adopted for the geocentric coordinates of the Sun are rendered definite, and if the final corrections δv, δu, and $\delta\frac{1}{r}$ are found on the assumption that $\delta v'$ contains no terms of the form

$$\delta(l'+n't)$$

or

$$\delta l'+\delta n'.t+n'\delta t,$$

then the resulting functions,

$$v+\delta v,\ u+\delta u,\ \frac{1}{r}+\delta\frac{1}{r},$$

will, if complete, be the expressions for the geocentric coordi-

nates of the Moon when t is found from observation, subject to the conditions indicated, that $\delta v'$ contains no terms of the form

$$\delta(l'+n't)$$

or

$$\delta l'+\delta n't+n'.\delta t,$$

but not otherwise.

If such corrections as $\delta l'+\delta n'.t+n'.\delta t$ exist and are sensible, the effects of such terms on the integrals $\delta v.\delta u$. and $\delta.\frac{1}{r}$ must be investigated, and included in the expressions for $v+\delta v.u+\delta u\ \frac{1}{r}+\delta\frac{1}{r}$ before the theoretical results are compared with observation for the determination of the numerical values of the constants involved in their expression. But if $\delta l'+\delta n'.t+n'.\delta t$ is put equal to zero, then the variable t, or the time, must be found subject to the same conditions; and this requires, in order that $\delta t=0$, or the time, t, be found correctly, that $\delta l'=0$ and $\delta n'=0$, or that the epoch from which t is measured, and the unit in which it is expressed, shall be such that the adopted values l' and n' are exact.

If the integrals of the differential equations of motion are correctly found in terms of the variable t, which renders $\delta l'=0$, $\delta n'=0$, or the adopted values of l' and n' exact, and we employ in making the comparisons between theory and observation a value $t+\delta t$ instead of t, the effects of the errors, δt, will be thrown upon the determinations of the constants; and this will be true however the variable $t+\delta t$ may be found from observation, provided it differs from the time, t, on the required scale of time measurements; and if δt is of the form $P \sin(pt+q)$, the determinations of the epoch-constants and mean motions will appear liable to periodical changes which cannot be accounted for, quantitatively, by direct theoretical investigations of the motions of the planets and of the Moon, based on the usual assumption that $\delta(l'+n't)=0$. There will appear in such cases a necessity for empirical long inequalities to secure an agreement between the tabular results and those of observation. But such empirical corrections should, I believe, be most carefully avoided, and attention directed to the theoretical inequalities in solar theory to avoid errors, δt, and to the completion of the theories of the planets and Moon on the present assumption that $\delta(l'+n't)=0$. It may be mentioned that the right ascensions of the stars are found subject to the same condition, and that from them the right ascensions of the meridians are interpolated by the aid of clocks, and rendered definite by direct references to the Sun's positions at the meridian passages.

On the Determination of a certain Class of Inequalities in the Moon's Motion. By Ernest W. Brown, B.A.

1. The two principal methods of treating the Lunar Theory—viz. (1) the *general* method, in which we obtain a general approximate solution, applying to any single Moon whose present orbit lies within given limits, in terms of certain constants, the coordinates of position and the time; and (2) the *special* method, in which we use the numerical values of those constants at the outset for any given Moon, and obtain a solution involving the coordinates of position and the time only—present each of them certain advantages. In the first case, we have the theory, worked out to a certain degree of accuracy, immediately applicable to any single Moon in our solar system, and therefore arranged in such a way that any small change which improved data may involve in the values of the constants can be made easily without requiring us to go over the whole of the work again. On the other hand, the number of terms which have been found necessary to secure a degree of accuracy commensurate with that of observation is very large, and it becomes a task of great labour to obtain them with any degree of certainty. In the second case, when we use numerical values from the start, the portions arising from the expansion of the functions in ascending powers of the constants involved, which portions in the first case would have to be neglected, are no longer left out of account. A great increase of accuracy naturally results. But this method is unsatisfactory in some respects. Having started with certain values of the constants for any particular Moon, we are bound to keep to those values; and also if any numerical mistake be made, it is not very easily traceable. The calculation is applicable only to the particular Moon selected. Any method, therefore, of finding the path of the Moon which will give at the same time numerical and algebraical results with equal accuracy would be of value.

Mr. G. W. Hill, in the *American Journal of Mathematics*, vol. i.,* has shown how to separate out those inequalities dependent *only* on the ratio of the mean motions of the Sun and Moon, and to obtain their coefficients both numerically and as an algebraic function in ascending powers of this ratio. He shows also that his method is not only susceptible of a very high degree of accuracy with comparatively little trouble, but that any higher degree of accuracy can be obtained without the necessity of going over a large part of the ground again. His method for this class of inequalities is as follows:—

2. Take as origin the centre of the Earth considered as a sphere, and refer the motion to rectangular axes revolving round the origin with the mean angular velocity n' of the Sun round the Earth. If we neglect all the differences from purely elliptic

* *Researches in the Lunar Theory*, pp. 5, 129, 245

motion, but those dependent on the mean motions of the Sun and Moon, the Sun will describe a circle about the Earth with constant angular velocity n', and we may therefore assume the moving axis of x to pass through the Sun. Under these circumstances, the equations of motions of the Moon become

$$\left.\begin{aligned} &\frac{d^2x}{dt^2} - 2n'\frac{dy}{dt} + \left(\frac{\mu}{r^3} - 3n'^2\right)x = 0 \\ &\frac{d^2y}{dt^2} + 2n'\frac{dx}{dt} + \frac{\mu}{r^3}y \qquad\quad = 0 \end{aligned}\right\} \quad \ldots\ldots\ldots \quad \text{I.}$$

These equations will give us all inequalities from purely circular motion, which involve only the eccentricity of the Moon and the mean motions of the Sun and Moon. By taking certain "particular integrals" of these equations, the inequalities dependent only on the mean motions can be separated out and determined. This particular solution is given by

$$x = \Sigma a_{2i} \cos(2i+1)(n-n')(t-t_0)$$
$$y = \Sigma a_{2i} \sin(2i+1)(n-n')(t-t_0),$$

when i takes integral values positive and negative, and a_{2i} is a function only of the ratio of the mean motions of the order m^{2i} at least. The quantities a_{2i} are then determined by substituting this particular solution in the equations of motion. Certain transformations are first made in order to reduce the equations (I) to a convenient form.

3. In most previous methods, and especially in Delaunay's, the coefficients of this class of inequalities are expressed directly in ascending powers of $n'/n = m$; but in Mr. Hill's method of preparing the equations for solution the function of m which appears most naturally for use is $n'/(n-n')$. Let

$$m_1 = \frac{n'}{n-n'}, = \frac{m}{1-m};$$

we then have

$$m = \frac{m_1}{1+m_1}.$$

At first sight m_1 would seem to be a less suitable quantity than m, since m_1 is greater than m, and consequently a greater number of terms would seem to be required to obtain a given degree of accuracy. But it is shown that the numerical multipliers of the higher powers of m_1 are much smaller than those of the corresponding series in m; in other words, the series for the coefficients expressed in ascending powers of m_1 are so much more convergent than the same series expressed in powers of m, as to quite overbalance the disadvantage of m_1 being slightly greater than m. Further, he shows that by using a certain function of m_1 *obtained theoretically*, for expansion, the series can be ren-

dered still more convergent. This function of m_1 is μ, where μ is given by

$$\mu = \frac{m_1}{1 - \frac{1}{3}m_1} = \frac{m}{1 - \frac{4}{3}m}.$$

Hence

$$m = \frac{\mu}{1 + \frac{4}{3}\mu}.$$

The series for a_{2i} are given by Mr. Hill, developed in terms of both m_1 and μ.

4. These transformations can be utilised also in another way. The inequalities found as indicated in § (2) are referred to rectangular coordinates. It has been usual to refer the Moon's motion to polar coordinates. We have for this purpose

$$r \cos v = \Sigma a_{2i} \cos 2i\,(n - n')\,(t - t_0)$$
$$r \sin v = \Sigma a_{2i} \sin 2i\,(n - n')\,(t - t_0),$$

where r is the radius vector and v the excess of the true over the mean longitude. From these r and v can be easily found.

The process of finding these coefficients as algebraic expansions in powers is somewhat laborious when, as in the special case of the Variation Inequality, it is necessary to carry the expansions to a high power. But there is no reason why, supposing Delaunay's expressions in longitude and parallax for these coefficients to be accurate as far as they go, we should not put in them

$$m = \frac{\mu}{1 + \frac{4}{3}\mu},$$

and expand in powers of μ. This transformation gives us smaller numerical multipliers of the higher powers, and consequently greater accuracy when we substitute for μ its numerical value. It is to be noted that if the given series is calculated as far as m^q, the transformed series cannot be carried further than μ^q.

5. As an example, take that part of Delaunay's expression* for the coefficient of the Variation which depends on m. It is

$$\frac{11}{8}m^2 \quad + \frac{59}{12}m^3 \quad + \frac{893}{72}m^4 \quad + \frac{2855}{108}m^5 \quad + \frac{8304449}{165888}m^6$$
$$1586''\!\cdot\!8883 \quad + 424''\!\cdot\!4474 \quad + 80''\!\cdot\!0906 \quad + 12''\!\cdot\!7689 \quad + 1''\!\cdot\!8087$$
$$+ \frac{102859909}{1244160}m^7 \quad + \frac{7596606727}{74649600}m^8 \quad - \frac{8051418161}{1119744000}m^9 \;\ldots \quad (a)$$
$$+ 0''\!\cdot\!2234 \quad + 0''\!\cdot\!0206 \quad - 0''\!\cdot\!0001$$

where the coefficients expressed in seconds are written underneath. Putting *in this series*

$$m = \mu/(1 + \tfrac{4}{3}\mu),$$

* Delaunay, *Mémoires de l'Académie des Sciences*, tome xxix. p. 815.

and expanding in powers of μ, it becomes

$$\begin{array}{ccccc} \frac{11}{8}\mu^2 & +\frac{5}{4}\mu^3 & +\frac{5}{72}\mu^4 & -\frac{11}{36}\mu^5 & -\frac{82111}{165888}\mu^6 \\ 1957''\cdot9686 & +147''\cdot8944 & +0''\cdot6827 & -0''\cdot2496 & -0''\cdot0336 \end{array}$$

$$\begin{array}{cccc} -\frac{350399}{138240}\mu^7 & -\frac{233559113}{74649600}\mu^8 & -\frac{10961275281}{1119744000}\mu^9 & \ldots \quad (\beta) \\ -0''\cdot0143 & -0''\cdot0015 & -0''\cdot0004 & \end{array}$$

The values of the coefficients obtained from these expressions are—

$$\left.\begin{array}{ll} \text{From } (a) \;\ldots\;\ldots\;\ldots & 2106''\cdot2478 \\ \text{From } (\beta) \;\ldots\;\ldots\;\ldots & 2106\cdot2463 \\ \text{From Mr. Hill's values} \;\ldots & 2106\cdot2463 \end{array}\right\} \ldots\ldots \quad (\gamma)$$

The last value has been calculated from the numerical values of the coefficients a_{2i} given in his paper already referred to. The equality of the second and third values—the second obtained from Delaunay's series when expressed in terms of μ, and the third from Mr. Hill's numerical values—is striking. It not only shows us the improvement in accuracy afforded by such transformations, but it gives us also some security for the general correctness of this particular part of Delaunay's expression for the coefficient of the variation.

6. There appears to be a kind of oscillation in the class of series of which (a) or (β) is an example. For instance, in the series (a) the numerical multipliers are positive, and increase gradually until a change of sign occurs between m^8 and m^9, when there is a sudden drop. The numerical values (γ) seem to show that there must be a large increase in the multipliers of the powers after m^9, and that they must have negative signs; so that probably the multipliers of m^{10} and m^{11} are much larger than even those of m^7 or m^8. The series (β) has a sudden drop between μ^3 and μ^4, and then a change of sign occurs, after which the multipliers gradually increase again. I have calculated similar expressions in the coefficients of other inequalities, and generally it appears that when we, by any such substitution as that made above, apparently improve the convergency of the series, the change of sign is brought nearer to the beginning of the series. An ideal to aim at would seem to be, firstly, that the numerical multipliers be made as small as possible; secondly, that there be no sudden increase in them in the later part of the series; and thirdly, that these two conditions should involve that there be no long run of powers with the same sign attached to them. This appears very forcibly in the expressions for the Parallactic Inequality given in § (11) below. It should be stated that as the series are calculated up to some definite power only,

and as the law of progression of the series is not able to be expressed by an algebraical formula, owing to the complicated forms from which they arise, a substitution like that made above *must not be arbitrary*, but must be indicated by theory. An arbitrary substitution, which would seem to make the parts of the series already calculated converge rapidly, may make the unknown part very slowly convergent, and thus introduce unknown errors into the numerical values of the coefficients.

7. It has been mentioned above that the equations (I.) determine all the inequalities dependent on the eccentricity and the mean motion only. As in these equations when transformed for solution m_1 and not m is the quantity which appears, all those series which depend on the eccentricity and mean motions only will probably be rendered more convergent when expressed in terms of m_1. Consequently, in Delaunay's expressions involving e and m only, we are entitled to put $m=m_1/(1+m_1)$, and expand in powers of m_1 up to the same power of m_1 as that to which m was carried; the result of this should be more convergent series and greater accuracy in the coefficients when expressed in seconds. It will be found on examination that nearly all these series have a number of successive powers of m of the same sign with gradually increasing multipliers; and the transformation improves the series in the manner mentioned in § (6).

8. When we examine Delaunay's expression for the part of the coefficient of the Parallactic Inequality dependent on the ratios of the mean distances and mean motions, we notice that the numerical multipliers of the higher powers of m become very large. The multiplier of any one power is between four and seven times that of the previous power; and since m is in the case of our Moon about ·074, the series expressed in seconds converges very slowly. The expression is given below in § (11). In fact, the last term calculated, which is of the ninth order, corresponds to a coefficient of $0''\!\cdot\!38$; so that some method is necessary for this inequality which will give us either more terms easily, or a new form of expression with greater convergency. I shall give elsewhere the analysis by which the expressions and values below have been obtained, and expose only the method used to work up the coefficients into a more convergent form. No other inequalities but those given are affected thereby.

In obtaining these inequalities dependent on m and the ratio of the mean distances, some terms of the disturbing function have to be added to the left-hand sides of the equations (I.). The constant m_1 is still the function of m which appears naturally for use in expansion. The general method of procedure has been the same as that Mr. Hill used in getting the inequalities dependent on the mean motions only.

9. Let a denote the mean semi-axis major of the Moon's orbit, a' that of the Sun's orbit, v the difference between the true and mean longitudes of the Moon, 2D the argument of the variation

in Delaunay's theory; the parts of the Lunar Inequalities dependent on the mean motions and a/a' only, appear in the following form:—

$$r \cos v = a_0 + (a_1 + a_{-1}) \cos D + (a_2 + a_{-2}) \cos 2D + \dots$$
$$r \sin v = \quad (a_1 - a_{-1}) \sin D + (a_2 - a_{-2}) \sin 2D + \dots$$

The quantities $a_{\pm p}$ are functions of the kind,

$$\frac{a_{\pm 2p}}{a} = f(m_1) + \left(\frac{a}{a'}\right)^2 \phi(m_1) + \dots$$
$$\frac{a_{\pm 2p+1}}{a} = \frac{a}{a'} F(m_1) + \left(\frac{a}{a'}\right)^3 \Phi(m_1) + \dots$$

where p is a positive integer.

In the functions f for a_{2p}, m_1^{2p} is the lowest power of m_1 which occurs; in F the lowest power is also m_1^{2p}, except when $p=o$, when it is m_1; when $p=o$, f is of the form $1+\alpha m_1^2+\beta m_1^3+\dots$, α, β, .. being numbers. Mr. Hill, in his paper referred to, has given the functions f, and his values for them have been used in obtaining the functions F, ϕ, Φ.

When we transform these expressions to polar coordinates, we have, neglecting cubes and higher powers of a/a',

$$v = A\frac{a}{a'} \sin D + \left\{B + B'\left(\frac{a}{a'}\right)\right\} \sin 2D + C\frac{a}{a'} \sin 3D + \dots$$

where A, B, B′, C ... are functions of m_1. D is the argument of the Parallactic Inequality, and the first term represents the principal part of it, *i.e.* the part dependent on m_1 and a/a' only. The full expression of this inequality contains terms dependent on the solar and lunar eccentricity and the lunar inclination, but we are not here concerned with such terms, and they do not affect the expressions which follow.

10. The principal part of the coefficient Aa/a' depends chiefly on a_1/a and a_{-1}/a. In obtaining a_1 and a_{-1} as far as the order $m_1^5 . a/a'$, it is possible so to arrange the work that the equations determining them are linear and of the form

$$\frac{a_1}{a_0} . \alpha_1 + \frac{a_{-1}}{a_0} . \beta_1 = \kappa_1 . \frac{a}{a'},$$
$$\frac{a_1}{a_0} . \alpha_2 + \frac{a_{-1}}{a_0} . \beta_2 = -\kappa_2 . \frac{a}{a'}$$

where α_1 α_2 β_1 β_2 κ_1 κ_2 are functions of m_1 expanded in ascending powers of m_1, and the signs in the equations are so arranged that these functions become positive numerical quantities in the special case of our Moon.

Solving these equations for a_1 and a_{-1} we have

$$\frac{a_1}{a_0} = -\frac{\kappa_1\beta_2+\kappa_2\beta_1}{\beta_1\alpha_2-\alpha_1\beta_2} . \frac{a}{a'} \qquad \frac{a_{-1}}{a_0} = +\frac{\kappa_1\alpha_2+\kappa_2\alpha_1}{\beta_1\alpha_2-\alpha_1\beta_2} . \frac{a}{a'}.$$

The expressions on the left-hand sides of these equations, when for α_1 β_1, etc. are substituted their expansions in powers of m_1, are cumbrous. At the same time, when α_1 β_1, etc. are given their numerical values, we get a very close approximation to the results obtained by the more accurate method of using numerical values from the start. Each of these quantities, when expanded in powers of m_1, converges quickly and no very large numerical multipliers seem to appear. But the multipliers in all of them gradually increase, and consequently, when we express the products $\kappa_1\,\beta_2$, $\kappa_2\,\beta_1$, etc., in ascending powers of m_1, larger multipliers occur. It seems best, however, for simplicity to expand the numerators and denominators of the expressions for a_1/a_0 and a_{-1}/a_0, and leave the results in the form of fractions which have the same denominator. The loss in accuracy is very small. We have then

$$\frac{a_1}{a_0} = -\frac{\gamma(m_1)}{\tau}\,\frac{a}{a'} \qquad\qquad \frac{a_{-1}}{a_0} = +\frac{\delta(m_1)}{\tau}\cdot\frac{a}{a'}$$

where γ, δ, τ are functions of m_1 expanded in ascending powers.

11. The terms in longitude with arguments D, 3D, 5D, calculated in this way, become

$$\left[-\frac{\frac{15}{8}m_1+\frac{9}{4}m_1^2-\frac{1951}{128}m_1^3-\frac{41585}{1024}m_1^4-\frac{2096751}{49152}m_1^5}{1-4m_1-\frac{37}{8}m_1^2-\frac{17}{6}m_1^3-\frac{89963}{9216}m_1^4}\right.$$

$$\left.-\frac{35}{1024}m_1^4-\frac{1345}{12288}m_1^5\right]\times\frac{a}{a'}\sin D$$

$$-124''\cdot1493 \qquad -12''\cdot0447 \qquad +6''\cdot5970 \qquad +1''\cdot4218 \qquad +0''\cdot1207$$

$$-0''\cdot0008 \qquad -0''\cdot0002$$

$$\left[+\frac{15}{32}m_1^2+\frac{55}{128}m_1^3-\frac{41}{1536}m_1^4+\frac{2309}{9216}m_1^5-\right.$$

$$\left.\frac{\frac{255}{128}m_1^3+\frac{7543}{1536}m_1^4-\frac{134525}{8192}m_1^5}{1-4m_1-\frac{37}{8}m_1^2-\ldots}\right]\times\frac{a}{a'}\sin 3D$$

$$+1''\cdot6172 \qquad +0\cdot1199 \qquad -0''\cdot0006 \qquad +0''\cdot0005$$

$$-0''\cdot8624 \qquad -0''\cdot1718 \qquad +0''\cdot0470$$

$$\left[+\underbrace{\frac{75}{128}m_1^4+\frac{2797}{2048}m_1^5-\frac{18415}{8192}m_1^6\times\frac{1}{1-4m-\ldots}}_{+0''\cdot0093}\right]\times\frac{a}{a'}\sin 5D.$$

For the sake of comparison I give Delaunay's expressions* for the same terms; they are expanded in powers of m.

$$-\left[\frac{15}{8}m+\frac{93}{8}m^2+\frac{6887}{128}m^3+\frac{137197}{512}m^4+\frac{4628333}{3072}m^5+\frac{631068813}{8192}m^6\right.$$

$$-74''\cdot 0235 \quad -34''\cdot 3297 \quad -11''\cdot 8852 \quad -4''\cdot 4276 \quad -1''\cdot 8621 \quad -0''\cdot 7122$$

$$\left.+\frac{108355371159}{196608}m^7\right]\frac{a}{a'}\sin \mathrm{D}$$

$$-0''\cdot 3811$$

$$+\left[\frac{15}{32}m^2-\frac{5}{8}m^3-\frac{259}{16}m^4-\frac{666249}{6144}m^5\right]\frac{a}{a'}\sin 3\mathrm{D}$$

$$+1''\cdot 3843 \quad -0''\cdot 1381 \quad -0''\cdot 2675 \quad -0''\cdot 1340$$

$$+\left[\frac{75}{128}m^4+\frac{3911}{1024}m^5\right]\frac{a}{a'}\sin 5\mathrm{D}$$

$$+0''\cdot 0097 \quad +0''\cdot 0047$$

The gain in accuracy by the former mode of expression is evident; the terms there are carried only as far as m_1^5, while Delaunay's go as far as m^7.

The equations for obtaining a_1 a_{-1} involve largely a_2 a_{-2}, which go to form the coefficient of the Variation. It has been mentioned that the expansions of these quantities are much more convergent when expressed in terms of μ, § (3). Hence it is probable that the resulting expressions for the coefficients of the Parallactic Inequality would be also rendered more convergent when expressed in terms of this quantity. This inequality thus transformed becomes,

$$-\left[\frac{\frac{15}{8}\mu+\mu^2-\frac{2158}{128}\mu^3-\frac{175705}{9216}\mu^4+\frac{3261161}{442368}\mu^5}{1-\frac{13}{3}\mu-\frac{133}{72}\mu^2+\frac{91}{216}\mu^3-\frac{701891}{82944}\mu^4}+\frac{35}{1024}\mu^4+\frac{785}{12288}\mu^5\right]\frac{a}{a'}\sin \mathrm{D}.$$

$$-131''\cdot 1311 \quad -5''\cdot 8109 \quad +8''\cdot 1438 \quad +0''\cdot 7648 \quad -0''\cdot 0246 \quad -0''\cdot 0009 \quad -0''\cdot 0001$$

[In making the transformation, both numerator and denominator of the expression given at the beginning of this section must be multiplied by m_1, and, in the result, for m_1 must be put $\mu/(1+\frac{1}{3}\mu)$. It is in that form that the expression occurs.] The series in both numerator and denominator seem slightly more convergent, and the numerical result is a little closer to the final value.

12. To exhibit the values of the coefficients obtained by using these several expressions, a table is given. In column (i.) is the argument of the term; in (ii.) the coefficients found by using the numerical value of m_1 from the start; (iii.) those found by

* Delaunay, *Mém. cit.* pp. 847, 856, 860.

putting the numerical values of α_1 β_1, etc. in the expressions of § (10); (iv.) gives the values from the expressions in terms of m_1 in § (ii.); (v.) those in terms of μ in the same section; in (vi.) are Delaunay's values. No estimate of neglected terms is taken into account.

i.	ii.	iii.	iv.	v.	vi.
D	$-128''.069$	$-128''.073$	$-128''.056$	$-128''.059$	$-127''.621$
3D	$+\ 0.750$	...	$+\ 0.749$	...	$+\ 0.845$
5D	$+\ 0.008$	...	$+\ 0.009$	...	$+\ 0.014$

The column (ii.) gives the final values to be used; (iii.), (iv.), or (v.) may serve also as checks on the numerical work. It may be noticed that in obtaining the numerical values from the outset it is only necessary to substitute for m_1 its value. The ratio a/a' occurs only in its first power; it may therefore be kept as a factor right through, and its numerical value substituted as the final step.

13. The expansions I have given for the parallactic terms, when transformed, agree with those of Delaunay as far as the terms of the sixth order. The numerical multipliers of $m^5.a/a'$ differ by small quantities; these differences would not, however, cause differences in the coefficients expressed in seconds of more than $0''.004$. As the coefficient of the term with argument 5D is very easily obtainable by the methods indicated, I am inclined to attribute some small numerical errors to Delaunay. Newcomb suggests * that Delaunay's multiplier of $m^7 a/a'$ may be wrong. I have not yet been able to test Delaunay's multipliers of $m^6.a/a'$ and $m^7.a/a'$ owing to the large amount of labour they entail. But that the numerical values given in column (ii.) of the table do not differ by more than one or two thousandths of a second from the true values can be seen during the progress of the work necessary for finding those values.

14. The corresponding terms in the expression for the Moon's parallax, which I have obtained, are :—

$$-\frac{1}{a}\left[\frac{\frac{15}{16}m_1+\frac{3}{8}m_1^2-\frac{1869}{256}m_1^3}{1-4m-\frac{37}{8}m^2-\ldots}\right]\frac{a}{a'}\cos \mathrm{D}.$$

$$-1''.0291 \quad -0''.0333 \quad +0''.0524 \quad = -1''.0100.$$

$$+\frac{1}{a}\left[\frac{25}{64}m_1^2+\frac{65}{256}m_1^3-\frac{459}{256}\cdot\frac{m_1^3}{1-4m_1-\ldots}\right]\frac{a}{a'}\cos 3\mathrm{D}.$$

$$+0''.0223 \quad +0''.0012 \quad -0''.0139 \quad = +0''.0096.$$

* Newcomb, *Transformation of Hansen's Lunar Theory*, Astronomical Papers for Use of American Ephemeris, vol. i., part ii.

Delaunay's expressions * for the same being

$$-\frac{1}{a}\left[\frac{15}{16}m+\frac{81}{16}m^2+\frac{5817}{256}m^3\right]\frac{a}{a'}\cos D.$$

$$-0''\cdot6136 \quad -0''\cdot2479 \quad -0''\cdot0832 \quad = -0''\cdot9447.$$

$$+\frac{1}{a}\left[\frac{25}{64}m^2-\frac{115}{128}m^3\right]\frac{a}{a'}\cos 3D.$$

$$+0''\cdot0191 \quad -0''\cdot0033 \quad = +0''\cdot0158.$$

The coefficients obtained by using numerical values from the start are $-1''\cdot0010$ and $+0''\cdot0080$, to which the former pair approximate closely.

15. A comparison of these new values with those given by Hansen cannot be complete owing to the fact that Hansen's numerical values contain the terms due to eccentricity and inclination. But a rough estimate of the uncalculated parts of these series may be made from Delaunay's expressions, since they are carried to a higher degree of approximation for numerical purposes than the terms we have been considering. The whole coefficient of the Parallactic Inequality in the longitude then becomes

$$127''\cdot30$$

Newcomb's method of transformation † shows that this coefficient when expressed in Hansen's notation is

	124·54″
Hansen's coefficient is	124·43
Diff.	0·11

The difference is probably partly due to a wrong estimate of the omitted terms in Delaunay's coefficient.

Haverford Coll., Pa., U.S.A.

Secular Perturbations of the Earth's Orbit by Mars.

By R. T. A. Innes.

In Professor Hill's "Theory of *Jupiter* and *Saturn*" he mentions that the terms arising from the fifth powers of the eccentricities and inclination amount to one per cent. of those of the first order in the case of *Mars* and the Earth, and that a computation by Gauss's method would be desirable. I have therefore

* Delaunay, *Mém. cit.* pp. 922, 923.
† Newcomb, *Mém. cit.*

made it. To let the comparison with Le Verrier's results be an exact one, I have used the same elements as Le Verrier in "Les Annales de l'Obs. de Paris," *Mémoires*, tome ii. The formulæ used are Professor Hill's, in the appendix to his paper on Gauss's method, published in the Astronomical Papers of the American Ephemeris, where the signification of the symbols will be found.

As a guide to future computers, I give the chief figures involved. This will also lead more easily to the detection of any errors I may have made.

Le Verrier's elements and Professor Hill's formulæ give:

$$\Pi = 51^\circ\ 58'\ 55''\cdot25,\ \sin\Pi = [9\cdot8964256]$$

$$\Pi' = 284\ 55\ \ 5\cdot75,\ \tan\Pi' = [n0\cdot5744319]$$

$$K = 127\ \ 3\ 22\cdot70$$

$$K' = K + 53''\cdot59$$

$$k = [9\cdot9997883]$$

$$k' = [9\cdot9999849]$$

$$r = 1 - [8\cdot2245450]\cos E$$

$$\tan\frac{v}{2} = [0\cdot0072840]\tan\frac{E}{2}$$

$$\nu' = \frac{\sqrt{3}}{32m_1{}^2}\left\{1 + 2\frac{\lambda^4}{m_1{}^2m_{11}{}^2} + 4\frac{}{m_1{}^6m_{11}{}^4m_{111}{}^2} + \right\}$$

$$\operatorname{Log}\frac{\sqrt{3}}{32} = 8\cdot7334106\cdot49.$$

$$A = r^2 + [9\cdot4534182]r\cos(v + 127^\circ\ 3'\ 22''\cdot70) + 2\cdot3216353$$

$$B\cos\epsilon = 0\cdot2165194\cdot5 + [0\cdot1826853]r\cos(v + 127^\circ\ 3'\ 22''\cdot70)$$

$$B\sin\epsilon = [0\cdot1809850]r\sin(v + 127^\circ\ 4'\ 16''\cdot29)$$

$$C = 0\cdot0201929\cdot5 = [8\cdot3051998]$$

$$F_1 = [9\cdot6379998]\frac{B^2 - AC}{3q}$$

$$F_2 = [n8\cdot9713730]\frac{B\sin\epsilon}{q}$$

$$F_3 = F_2 \times [8\cdot5095314]r\cos(v + 51^\circ\ 58'\ 55''\cdot25)$$

$$J_1 = 1 - [7\cdot0186092]\sin^2(v + 51^\circ\ 58'\ 55''\cdot25) - p[9\cdot9390298]$$

$$J_2 = [8\cdot7903880]r\sin(v + 127^\circ 3' 22''\cdot70) - [7\cdot0186092]\sin(v + \Pi)\cos(v + \Pi)$$

$$J_3 = [8\cdot5090779]r\sin(v + 51^\circ\ 58'\ 55''\cdot25) - [7\cdot1963299]r^2$$

To find $A_0{}^{(c)}$ $B_0{}^{(c)}$ $C_0{}^{(c)}$, etc., etc., I divided E into sixteen parts, and the differences between the sums S and S_1 would seem to show that even division into sixteen parts is not too much.

The values of the functions involved are given in the following tables:—

E	r	v	A	B cos ε	Log B sin ε
0°	0·98322954	0° 0′ 0″·00	3·1200687	−0·6858181	0·0755814
22½	0·98450612	22 52 14·19	3·0488700	−1·0810004	9·8739366
45	0·98814149	45 41 0·71	3·0196127	−1·2763040	9·2765785
67½	0·99358222	68 23 26·31	3·0367939	−1·2419961	*n* 9·6040431
90	1·00000000	90 57 39·32	3·0978414	−0·9832986	*n* 9·9706386
112½	1·00641778	113 23 5·76	3·1934788	−0·5395969	*n* 0·1232717
135	1·01185851	135 40 31·73	3·3091284	+0·0215597	*n* 0·1826155
157½	1·01549388	157 51 53·67	3·4271406	+0·6147402	*n* 0·1727356
180	1·01677046	180 0 0·00	3·5295059	+1·1496383	*n* 0·0901494
202½	1·01549388	202 8 6·33	3·6006222	+1·5448206	*n* 9·8968887
225	1·01185851	224 19 28·27	3·6296803	+1·7401243	*n* 9·3610636
247½	1·00641778	246 36 54·24	3·6123004	+1·7058160	9·5577875
270	1·00000000	269 2 20·68	3·5511707	+1·4471189	9·9513518
292½	0·99358222	291 36 33·69	3·4556156	+1·0034174	0·1097902
315	0·98814149	314 18 59·29	3·3401649	+0·4422605	0·1708793
337½	0·98450612	337 7 45·81	3·2223515	−0·1509200	0·1607256
S	8·00000000	1260 0 0·00	26·5971730	+1·8552810	
S	8·00000000	1440 0 0·00	26·5971730	+1·8552808	

E	p	q^2	r	θ	$\log m^2$	$\log n^2$	$\log \mu$
°				° ′ ″			
0	1.0332919	0.4598031	−0.1467474	−28 4 39.09	9.9941810	9.8022124	9.9504225
22½	1.0095590	0.4636798	−0.1820422	−35 12 32.37	9.9908244	9.8232810	9.9545353
45	0.9998066	0.4650408	−0.1973554	−38 29 8.24	9.9890222	9.8323854	9.9562339
67½	1.0055336	0.4635310	−0.1891672	−36 49 40.95	9.9899544	9.8278233	9.9553892
90	1.0258828	0.4598188	−0.1589229	−30 38 35.56	9.9930618	9.8099969	9.9519690
112½	1.0577619	0.4552393	−0.1127466	−21 32 5.19	9.9965827	9.7812503	9.9461238
135	1.0963118	0.4511423	−0.0596507	−11 21 11.10	9.9990520	9.7451285	9.9383598
157½	1.1356492	0.4482996	−0.0089750	− 1 42 48.42	9.9999784	9.7063832	9.9296824
180	1.1697710	0.4466968	+0.0318289	6 7 11.99	9.9997247	9.6710386	9.9215633
202½	1.1934764	0.4458017	+0.0581844	11 16 21.16	9.9990654	9.6455903	9.9156400
225	1.2031624	0.4451073	+0.0680766	13 15 9.53	9.9987079	9.6352922	9.9132303
247½	1.1973691	0.4445748	+0.0611672	11 54 30.39	9.9989569	9.6423159	9.9148744
270	1.1769926	0.4447342	+0.0381479	7 23 24.16	9.9995985	9.6649389	9.9201483
292½	1.1451409	0.4463320	+0.0009097	0 10 29.25	9.9999998	9.6982042	9.9278176
315	1.1066573	0.4497624	−0.0467645	− 8 55 8.66	9.9994151	9.7357938	9.9362916
337½	1.0673862	0.4546475	−0.0987180	−18 47 6.67	9.9974013	9.7719362	9.9441601
S	8.7918764	3.6221057	−0.4713877	−90 42 56.97	9.9727632	7.8967867	9.4882187
S′	8.7918763	3.6221057	−0.4713880	−90 42 52.80	9.9727633	7.8967844	9.4882228

E	log λ^2	log v'	log $\chi(r)$	$\psi(r)$	log V	$F_1\,\chi(r)$	$F_2\,\chi(r)$
0°	8·3430497	8·8305826	8·7453586	0·0741897	9·2013155	0·02167189	−0·00914170
22½	8·2919657	8·8228184	8·7132695	0·0696371	9·1650909	0·01831754	−0·00531459
45	8·2660437	8·8196212	8·7000483	0·0678487	9·1502562	0·01707298	−0·00130093
67½	8·2793701	8·8212164	8·7066194	0·0687315	9·1580297	0·01778349	+0·00281187
90	8·3254405	8·8276703	8·7332790	0·0724400	9·1883721	0·02054752	+0·00698228
112½	8·3845610	8·8386693	8·7790226	0·0793065	9·2394459	0·02569346	+0·01108019
135	8·4410573	8·8532282	8·8401553	0·0895794	9·3065140	0·03361226	+0·01468882
157½	8·4872642	8·8694241	8·9090100	0·1028612	9·3809596	0·04428206	+0·01687852
180	8·5205743	8·8845011	8·9739748	0·1173140	9·4504900	0·05643419	+0·01623644
202½	8·5407042	8·8954511	9·0217167	0·1292960	9·5013472	0·06694892	+0·01162539
225	8·5480973	8·8998932	9·0412263	0·1345584	9·5222568	0·07179179	+0·00354348
247½	8·5430985	8·8968888	9·0279064	0·1309423	9·5084480	0·06873565	−0·00540872
270	8·5256601	8·8871396	8·9853503	0·1200587	9·4634389	0·05925082	−0·01213458
292½	8·4956140	8·8729053	8·9238828	0·1059951	9·3976724	0·04721478	−0·01514318
315	8·4533278	8·8570930	8·8564791	0·0925550	9·3245542	0·03607853	−0·01486756
337½	8·4007099	8·8423608	8·7944432	0·0817742	9·2562021	0·02748428	−0·01252289
S.	7·4232509	0·7597292	8717	439		0·31646000	+0·00400625
S′.	7·4232877	0·7597342	8706	439		0·31646018	+0·00400660

E	$F_1\chi(v)$	J_1	J_2	J_3	$\log aa_1^2\cos\phi'/rq^{-\frac{1}{2}}$	$\frac{a}{r}R_0$	$\frac{a}{r}S_0$	$\frac{a}{r}W_0$
0°	−0·000178949	+0·1014009	+0·0479185	+0·02349328	0·7764402	0·2258587	−0·0091085	+0·0212508
22½	−0·000044194	+0·1217004	+0·0301830	+0·02916268	0·7724458	0·2138680	−0·0053317	+0·0249943
45	+0·000005543	+0·1301228	+0·0078447	+0·03008817	0·7724555	0·2100120	−0·0011380	+0·0252158
67½	−0·000045662	+0·1253943	−0·0158766	+0·02612875	0·7766056	0·2141949	+0·0031531	+0·0222048
90	−0·000180115	+0·1081083	−0·0375080	+0·01788717	0·7837667	0·2262802	+0·0072616	+0·0156809
112½	−0·000348768	+0·0807171	−0·0537719	+0·006609190	0·7919788	0·2459222	+0·0108250	+0·0049448
135	−0·000476155	+0·0472645	−0·0620825	−0·005962846	0·7992281	0·2719968	+0·0133181	−0·0106056
157½	−0·000480553	+0·0128394	−0·0610082	−0·01794022	0·8042171	0·3017932	+0·0140885	−0·0305409
180	−0·000328671	−0·0172021	−0·0505834	−0·02749054	0·8067070	0·3305172	+0·0125849	−0·0518088
202½	−0·000104440	−0·0381197	−0·0323730	−0·03315980	0·8072503	0·3519508	+0·0087020	−0·0681554
225	+0·000012731	−0·0466033	−0·0092457	−0·03408497	0·8065391	0·3604873	+0·0029870	−0·0725891
247½	−0·000084221	−0·0413425	+0·0151187	−0·03012524	0·8048474	0·3535068	−0·0034062	−0·0625137
270	−0·000304922	−0·0232433	+0·0368684	−0·02188354	0·8018745	0·3326480	−0·0089798	−0·0422440
292½	−0·000466545	+0·0047662	+0·0526579	−0·010614566	0·7971314	0·3034080	−0·0124533	−0·0195472
315	−0·000472020	+0·0382799	+0·0601789	+0·00196604	0·7905904	0·2726627	−0·0133480	−0·0003515
337½	−0·000348180	+0·0721729	+0·0584620	+0·01394311	0·7831251	0·2458188	−0·0119997	+0·0131515
	−0·001922558		−0·0066081	−0·01598724	6·3376016	2·2304629	−0·0035771	−0·1154515
	−0·001922563		−0·0066081	−0·01599610	6·3376016	2·2304627	0·0035776	−0·1154618

From which

$A_0^{(c)}$ =	+0·2788078	Log =	9·4453050
$\frac{1}{2}A_1^{(c)}$ =	−0·0263243		n 8·4203568
$\frac{1}{2}A_1^{(s)}$ =	−0·0266550		n 8·4257783
$\frac{1}{2}A_2^{(c)}$ =	−0·0003187		n 6·5033400
$B_0^{(c)}$ =	+0·0004472		6·6504737
$\frac{1}{2}B_1^{(c)}$ =	−0·0054333		n 7·7350613
$\frac{1}{2}B_1^{(s)}$ =	+0·0040225		7·6044961
$\frac{1}{2}B_2^{(c)}$ =	+0·0006491		6·8122989
$\frac{1}{2}B_2^{(s)}$ =	+0·0002348		6·3707906
$C_0^{(c)}$ =	−0·0144321		n 8·15933
$\frac{1}{2}C_1^{(c)}$ =	+0·0186839		8·271467
$\frac{1}{2}C_1^{(s)}$ =	+0·0149785		8·17547

And we have

$$\frac{m'n}{1+m} = [9·6844068].$$

These give

		Le Verrier's Values.
	$''$	$''$
$\left[\frac{de}{dt}\right]_{00}$	−0·018146	−0·01816
$e\left[\frac{d\varpi}{dt}\right]_{00}$	+0·018876	+0·01888
$\left[\frac{dp}{dt}\right]_{00}$	+0·007700	+0·00733
$\left[\frac{dq}{dt}\right]_{00}$	−0·008770	−0·00832
$\left[\frac{dL}{dt}\right]$	−0·270876	−0·2697

The differences are exceedingly small and tend to prove the general correctness of the calculation.

The differences in

$$\left[\frac{dp}{dt}\right]_{00} \text{ and } \left[\frac{dq}{dt}\right]_{00}$$

probably arise from the non-convergency of the function

$$\frac{m'}{2\mu}\mathrm{O}$$

in Le Verrier's expansion. The function

$$\frac{m'}{2\mu}\mathrm{G}$$

gives for the

$$\begin{array}{ll} \text{1st order} & -0''\cdot0096363 \\ \text{3rd} \;\;,, & -0\cdot0012981 \\ \text{5th} \;\;,, & -0\cdot0001487 \end{array}$$

from which we may estimate that the terms of higher orders will not exceed $-0''\cdot00002$.

The equation

$$\left[\frac{da}{dt}\right]_{\infty}=0$$

gives

$$\sin\phi\tfrac{1}{2}A_1^{(0)}+\cos\phi B_0^{(0)}=0,$$

Substituting the respective numbers I get

$$-0\cdot000447016+0\cdot000447108=0,$$

error—

$$+0\cdot000000092.$$

In making a similar operation on the figures, Professor Hill has given in his example of *Mercury*, perturbated by *Venus*, the difference is more considerable—viz.,

$$-0\cdot00075,$$

probably through a misprint of a figure in the value of R_0 or S_0.

In some parts of the calculations I have used eight decimals, and S and S_1 refer to the original numbers.

Sydney: 1891 *November* 1.

On the Spectrographic Method of determining the Velocity of Stars in the Line of Sight. By H. C. Vogel, Foreign Associate.

The experiments made at Potsdam in 1887 showed that, as a result of the extremely sensitive photographic methods employed, a sufficiently great dispersion could be made use of to readily detect and measure the displacement of the spectral lines produced by the motion of the stars in the line of sight. It very soon became clear that the measurement of the stellar spectra admitted of a far greater exactness than the direct observations, and that the disturbances of the atmosphere—the chief cause of the difficulties of the direct method—exert their influence in a lesser degree on the photograph. The very numerous measurements on more than two hundred negatives of forty-seven stars,

which are now available, have confirmed this result, and show further that the exactness of the measurements far surpasses the expectations based on the first plates taken with a provisional apparatus, and that the definitive observations have reached a degree of accuracy which in some cases is surprising.

This great accuracy has been secured by an advantageous construction of the apparatus, by its very exact adjustment, and especially by the peculiar methods adopted in measuring the photographs. I have already published several communications on this spectrographic method, viz. one in *Ast. Nach.*, No. 2896, a further one announcing the discovery of the motion of *a Virginis* (*Ast. Nach.*, No. 2995), and more recently an article on the employment of iron as a comparison spectrum in spectrographic researches (*Sitzungsberichte der Akademie zu Berlin*, June 4, 1891).

The reduction of the observations and measurements are at present nearly completed, but the passing through the press will still require several months, and therefore I now take the liberty of presenting a short review of the investigation and its chief results, in the hope that this summary, and more especially the explanation of the method of measuring the plates, may be of value and interest to many who are employed in similar lines of work.

In the construction of the apparatus the following points were taken into consideration: great stability for the smallest possible weight; suitable dimensions of prisms, collimator, and camera objectives, in order to preserve sufficient brightness with the greatest possible dispersion; accurate adjustment of the photographic plate in the focal plane of the camera objective; and exact keeping of the star on the slit of the spectrograph. I have endeavoured to satisfy the first two conditions by having the frame made of cast steel, and by giving it a form which offered the greatest possible resistance to flexure. The most suitable dimensions for collimator and camera objective, for the 12-inch refractor to which the spectrograph was to be applied, were found to be 408 mm. focal length for 34 mm. aperture.

The two Rutherfurd compound prisms have the following dimensions: Height (length of the refracting edge) 35 mm., breadth (perpendicular distance from the refracting edge of the flint-glass prism) 45 mm. They are of the most colourless glass obtainable, and the dispersion from F to H amounts for each to about 5°. The camera is constructed of sheet steel; the plate-holders are of brass and can be rigidly connected with the camera. The adjustment of the photographic film in the focal plane of the camera objective is accomplished by a motion of the latter, and can be effected with an accuracy of a fraction of a millimetre. In order to facilitate keeping the image of the star exactly on the slit, a small telescope is so connected with the apparatus that it receives the light which is reflected from the front side of the first prism.

The slit, illuminated by the Geissler tube, which furnishes the comparison spectrum, appears in this telescope as a narrow line of light with the star in the middle, and may be readily so held by means of the slow motions of the refractor. A cylindrical lens is not employed, since, with the slit set parallel to the line of the diurnal motion, a slight widening of the linear stellar spectrum can be readily effected by changing the rate of the driving clock. A very important point in the adjustment of this apparatus is that the optical axis of the collimator shall fall in the prolongation of that of the refractor; this is easily and accurately effected by three screws.

By means of a table giving the proper setting for various degrees of temperature the plane of the slit is, before each observation, adjusted to lie in the focus for the rays of the wave-length of $H\gamma$, for which the prisms are set at the angle of minimum deviation, and which appear on the middle of the negative. It is of great importance that the latter be precisely adjusted in the focus of the camera objective. This is likewise effected before each observation according to a table with the argument of the thermometer attached to the instrument. This table has been determined by many experiments, as well as by artificial warming of the apparatus. A false adjustment, which exerts a great influence on the sharpness of the images, and hence on the subsequent measurements, can be at once detected by the lack of distinctness of the image of the artificial hydrogen line, and, similarly, changes of the apparatus which occur during the exposure reveal themselves in the altered appearance of the comparison line.

In nearly all the observations hydrogen has been chosen for the comparison spectrum. The Geissler tube was placed directly in the cone of rays of the refractor, at a distance of 40 cm. from the slit, and was set at right angles to the optical axis of the refractor as well as to the slit, and therefore its light is to be regarded as dispersed on reaching the slit. The tubes used were very thin, so that only a comparatively small amount of light (17 per cent.) was lost in passing through them.

A further advantage of this arrangement of the Geissler tube lies in the fact that an exact adjustment of its position is not necessary, and any slight changes in its place during the exposure, due to an altered position of the instrument, can exert no injurious influence; for one can readily see that with an adjustment even several degrees false, the slit would still appear fully illuminated.

At first the time of exposure was regulated according to the brightness of the star and to the chosen width of slit, but later it appeared advantageous to leave the width unchanged at 0·02 mm. and to give a uniform exposure of one hour. The observer then, however, varied the width of the spectrum to correspond with the brightness of the star. The performance of the apparatus has been tested on the Sun by direct observa-

tions and by photographs. In the vicinity of $H\gamma$, where the spectrum is sharpest, nearly all the lines are visible which are contained in Rowland's large photograph of the solar spectrum, in spite of the comparatively small dimensions of the apparatus. Of course very close double lines cannot be separated if the width of the slit be greater than that corresponding to the distance between the lines.

One perceives less detail on the photograph than by direct observation, since, on account of the extraordinary delicacy of the lines, some details are lost through the coarseness of the silver grains. The excellent prisms would admit of a much greater magnification of the spectrum by the use of a camera objective of longer focus, and thus make possible the production of still sharper photographs, if the light-power of the refractor were not too small and the observations therefore necessarily limited to the brightest stars. I have given in *Ast. Nach.*, No. 2896, a collection of about fifty lines on one of the solar negatives which lie between 431·4 and 436·8 $\mu\mu$, and may remark further that my assistant, Dr. Scheiner, has been able to measure 290 lines in the spectrum of α *Aurigæ* between 412·4 and 466·8 $\mu\mu$.

In order to decide further as to the correct adjustment of the apparatus, numerous photographs of the Moon's spectrum, with that of hydrogen for comparison, have been made, and show an absolute coincidence of the corresponding lines. Two photographs of *Venus* are not without interest as showing the accuracy of the measures as well as the correctness of the adjustment:

	Observed Velocity.	Calculated Velocity.	
1889 Jan. 2	−7·8	−7·4	English miles.
Feb. 10	−7·4	−7·8	

The measurement of the spectra is accomplished with the aid of a microscope under the employment of magnifying powers from 7 to 35.

The table of the microscope carries a sliding apparatus, movable by a fine micrometer screw of 0·25 mm. pitch, to which the negative is firmly clamped. The periodic and progressive errors of this screw have been accurately determined. By means of a large number of measurements in the solar spectrum it has been found that one revolution of the screw corresponds to a difference in wave-length of 0·324 $\mu\mu$. With this value can now be computed g, the value in miles per second of velocity of one revolution of the screw, from the formula $g = \frac{\Delta\lambda}{\lambda} V$, where V is the velocity of light and λ the wave-length of $H\gamma$, 434·07 $\mu\mu$. The result is $g = 139{\cdot}13$ miles. This value, strictly speaking, holds good only for the temperature at which this standard photograph

of the solar spectrum was taken, since the dispersion varies with the temperature. A small correction has, therefore, been applied to all the photographs made at a different temperature. For stars of the second type, however, a method of measurement has been chosen which takes for a basis this standard solar negative, as I shall presently show.

In the case of the spectra of Classes II. and III., containing numerous lines, it suggested itself, in determining the displacement between the artificial Hγ and the star line, to connect the former by differential measurements with the other neighbouring lines, not only in order to obtain an increased degree of accuracy, but also indeed from necessity, since, in the generally very small displacements, it wholly or partly concealed the star line. All the difficulties which at first arose in the way of direct measurement of the plates, into the details of which I cannot here enter, were thereby overcome in that I simultaneously with the star spectrum also measured a standard solar spectrum taken with the spectrograph. The plate with the solar spectrum is cut off lengthwise, and so laid upon the star spectrum that the two appear in the microscope one above the other, and separated only by a small space.

The solar negative is observed through the glass, since, in order to avoid parallax, it must be inverted so that the two gelatine films are in contact. It is therefore cut off in order to obviate the effect of the unavoidable impurities in its gelatine film, through which otherwise the star spectrum would have to be observed. It can be then readily brought about that the lines of the one spectrum form the prolongation of those of the other.

The setting upon one of the threads of the system in the eyepiece of the microscope is effected solely by the motion of the above-mentioned sliding apparatus, to which both negatives are firmly attached. In the measurements four settings were usually made on a Sun line, then an equal number on the corresponding star line, those lines being sought out which, generally three on each side, lie nearest Hγ. The Hγ line in the star has only been measured when it was fully separated from the artificial line; but generally, instead of upon it, settings were made six or eight times on the solar Hγ, and an equal number on the artificial Hγ on the star plate.

The difference of the readings on the two spectra gives, in the mean, their displacement as compared with each other as they were brought together under the microscope; this mean, being applied to the difference of the settings on Hγ in the solar negative and the artificial Hγ due to the Geissler tube, gives the actual displacement of the star lines referred to the artificial line.

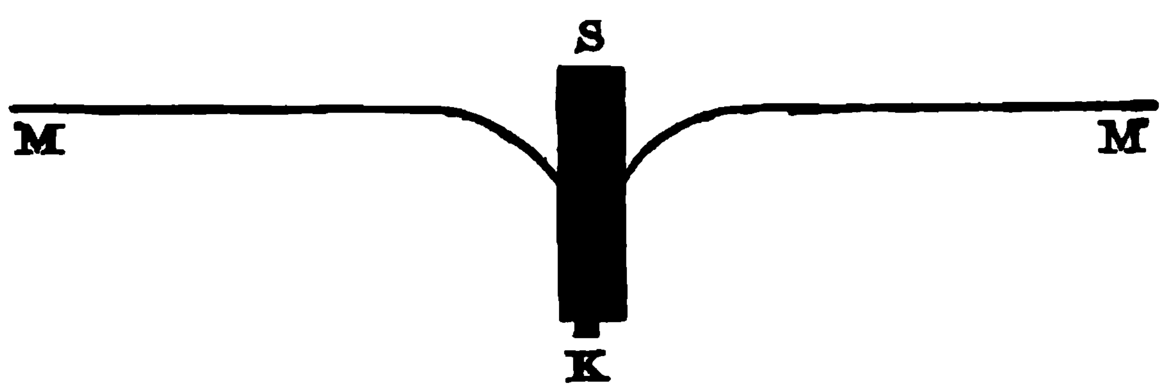
In most cases the star spectra have been photographed at other temperatures than the Sun, and the differences Sun–star are unequal and show a rate of progression. Under the assump-

tion of a simple proportional change, which is fully admissible for the small distances which alone come into question, a reduction to the dispersion of the solar negative must first be made, which has been done by the method of least squares.

The great advantage of this method of measurement lies in the fact that the unavoidable distortions in the sensitive film, which, owing to the smallness of the quantities to be measured, might easily come into consideration, are as much as possible eliminated, and also, further, that every prejudice of the observer is entirely eliminated, since the amount of the displacement is not directly obtained, but only after computation.

Most stars of the first spectral class show, in addition to the broad and strongly-marked hydrogen lines, a great number of other lines, so fine, however, that they can be distinctly recognised only in case of the brighter stars. The majority of these lines belong to the iron spectrum, and can be readily identified with solar lines; the measurement of the displacement can therefore either be made by reference to the solar negative, or, under the precautions which I have already stated in the article quoted, the iron spectrum may be used for comparison.

In the case of fainter stars of this class, however, one is restricted to the hydrogen lines, and if the more or less distinctly pronounced maximum of intensity lies outside of the artificial line, then the measurement presents no difficulty; but this is seldom the case, since the breadth of the maximum intensity corresponds to a difference in wave-length of about 0·03 $\mu\mu$, and a displacement of the artificial line only enough to bring its edge into coincidence with the position of maximum intensity would presuppose a velocity of fourteen miles. This maximum of intensity is generally not very sharply bounded, and, with this gradual decrease of the blackening on the negative, it could be accurately observed only in cases of a much greater displacement. The difficulties of this case were therefore insurmountable until a special procedure was thought out, which consisted in covering the Hγ star line, along with the artificial line, by a comparatively broad strip which was brought exactly over the middle of the Hγ line in the star. If, then, the thread of the micrometer be set on the middle of this strip, and the latter be then removed and the thread set on the artificial line, the difference in the readings will give the displacement.

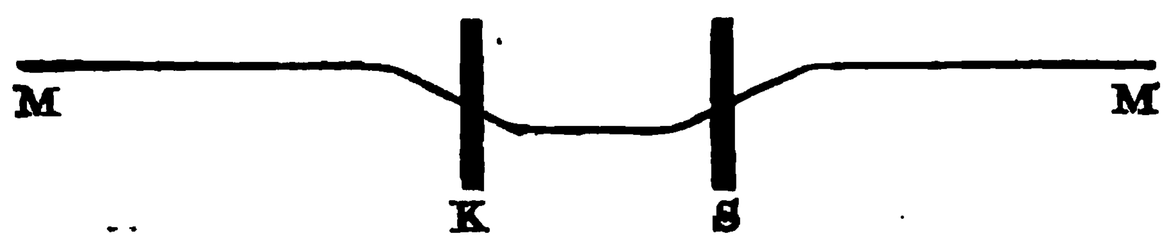


The accompanying figure will make the procedure clearer. M M is the intensity curve of the star spectrum in the vicinity

of Hγ, K is the artificial Hγ, displaced from the middle by the star's motion, and S is the strip covering the middle of the position of maximum intensity and the line K.

With a magnification such that the silver grains are readily perceptible, the setting of the strip over the middle of the broad Hγ line can, after some practice, be accurately accomplished by fastening the attention upon the density of the silver precipitate on the plate to right and left of the strip. From a series of small glass plates, upon each of which had been photographically produced a dark strip of differing width (from 0·05 to 0·20 mm.), the suitable one was chosen and laid directly upon the star negative, and fastened by a simple mechanical contrivance which allowed of its being moved backwards and forwards by a fine screw.

When the line in the star spectrum has been very broad and without a distinct position of maximum intensity, I have employed still another method in the measurement of stars with large velocities. A number of lines of varying breadth and blackness, but narrower than the strips just mentioned, were photographed upon small glass plates, and that one was then selected which most nearly equalled in breadth and blackness the artificial Hγ on the negative to be measured. The plate was then laid upon the star negative, and by the fine screw set upon the broad star line, so as to be symmetrical with the artificial Hγ. In the figure the star line is represented by the dipping of the curve M M, K is the line from the Geissler tube, to which is symmetrically set the line S on the glass plate. The micrometric measurement of the distance K S gives the double value



of the displacement. By practice much can here be gained in accuracy; attention to the silver grains is in this case also important. It has shown itself to be of advantage to repeat the measurements on different days, since very soon a certain habit of perception sets in which gives the measurements on a single day the appearance of an accuracy which is somewhat illusory.

The first result of any importance which the spectrographic method furnished was the proof of the influence of the Earth's motion on the displacement, which the earlier direct observations had failed to show with certainty. I append here a few examples:—

α Aurigæ.

Date.		Obs. Vel.	Earth's Vel.	Vel. of Star red. to ☉.
1888 Oct.	6	− 3·5	−15·4	+11·9
	22	+ 2·9	−13·0	+15·9
	24	+ 3·8	−12·6	+16·4
	25	+ 3·5	−12·4	+15·9
	28	+ 3·8	−11·8	+15·6
Nov.	9	+ 9·2	− 8·9	+18·1
Dec.	1	+10·8	− 2·9	+13·7
	13	+15·6	+ 0·7	+14·9
1889 Jan.	2	+20·2	+ 6·6	+13·6
Feb.	5	+30·8	+14·3	+16·5
May	6	+33·2	+17·0	+16·2
Sept.	15	− 3·6	−16·8	+13·2

α Tauri.

1888 Oct.	28	+18·1	− 9·5	+27·6
Nov.	10	+24·9	− 5·9	+30·8
Dec.	4	+30·6	+ 1·8	+28·8
1890 Jan.	9	+43·7	+12·3	+31·4

α Ophiuchi.

1888 Sept.	30	+27·6	+14·1	+13·5
1889 June	7	+ 9·7	− 1·0	+10·7

α Ursæ Majoris.

1888 Nov.	7	−17·0	−11·9	− 5·1
	9	−18·1	−11·9	− 6·2
1889 May	4	+ 5·2	+11·8	− 6·6
	22	+ 3·4	+11·2	− 7·8

A further result of the new method was the discovery of the changes in the motion of *Algol*, and thereby the proof of the existence of a dark satellite, for the determination of which the most delicate measurements were necessary. The discovery of the periodic motion of α *Virginis* then followed.

As an example of the accuracy of the method of symmetrical setting, which has been applied for stars with broad and ill-defined lines, and generally in the case of α *Virginis*, I give here the results of the measurements, with the period which I have deduced from them :—

α Virginis. Velocity in the line of sight − velocity of system

$$= 56{\cdot}7 \sin \left(\frac{t-t_0}{p}\right) 360°, \text{ in miles.}$$

Velocity of system = − 9·2 miles. Period, p, = 4·0134 days.

Epoch, t_0, = 1890 May 4, 10ʰ·50 Potsdam, m.t.

Date.		Obs. Vel. less Vel. of Translation.	Calc. Vel.	O.−O.
1889 April	21	−48·4	−53·5	+5·1
	29	−54·3	−52·1	−2·2
May	1	+50·7	+52·6	−1·9
1890 April	4	− 6·5	−12·4	+5·9
	9	−55·3	−56·2	+0·9
	10	+ 6·0	+10·6	−4·6
	11	+50·7	+56·2	−5·5
	13	−57·6	−56·2	−1·4
	15	+62·7	+56·2	+6·5
May	1	+53·5	+56·7	−3·2
	4	− 3·7	− 1·8	−1·9
	7	−61·3	−56·7	−4·6
	8	− 0·5	− 1·4	+0·9
	9	+63·2	+56·7	+6·5
	17	+61·8	+56·7	+5·1
	18	+ 6·0	+ 5·5	+0·5
	23	−65·5	−56·2	−9·3
	24	− 1·4	− 5·5	+4·1
	25	+53·0	+56·2	−3·2
	26	+ 5·1	+ 5·5	−0·4
	27	−52·6	−56·2	+3·6
	28	−12·9	− 8·8	−4·1
	31	−56·2	−56·2	0·0
June	4	−49·8	−55·8	+6·0
1891 April	24	+ 3·2	+ 4·6	−1·4
	27	+47·9	+45·2	+2·7
May	3	−58·1	−63·2	+5·1

As an example of the delicacy of the spectrographic negatives, I remark that in those of *β Aurigæ* not only has the periodic doubling of the lines been perceptible and well measurable in the magnesium line $\lambda = 448\ \mu\mu$, but also on some plates in other very fine lines in its vicinity. These observations may be found in *Ast. Nach.*, No. 3017.

In order now to give an illustration of the accuracy which is

attainable by the method of covering Hγ by a strip, I add my observations on *α Lyræ* and *α Canis Majoris*:—

α Lyræ.

	Obs. Vel.	Earth's Vel.	Star's Vel. red. to ☉.
1888 Sept. 28	− 2·6	+ 8·6	−11·2
Nov. 11	− 1·7	+ 7·0	− 8·7
13	− 1·5	+ 6·8	− 8·3
1889 May. 31	−10·7	− 4·8	− 5·9
June 6	− 9·9	− 4·0	− 5·9
Sept. 15	− 1·8	+ 8·1	− 9·9
Nov. 24	− 4·2	+ 5·7	− 9·9
25	− 6·7	+ 5·6	−12·3
26	− 7·2	+ 5·4	−12·6
	α Canis Majoris.		
1888 Dec. 13	−14·1	− 4·9	− 9·2
1890 Feb. 12	+ 0·8	+ 9·4	− 8·6
1891 Feb. 7	+ 0·1	+ 8·3	− 8·2
Mar. 21	+ 4·4	+13·8	− 9·4
22	+ 6·1	+13·9	− 7·8

I remark, further, that the observations of *Sirius* by the method of stars for the second class give 7·3 miles, and with the aid of the iron comparison spectrum 9·0 miles as the rate of approach towards the Sun.

In regard to the exactness of the measurements in general I will state that out of the average of all the observations the resulting probable error of a single negative for stars of Class II. is ±1·34 mile; for the stars of Class I. ±2·31.

Each star has on the average been observed 3·3 times, and the measurements have been made independently by myself and by Dr. Scheiner. It may, therefore, be concluded that the probable error of the definitive values for both spectral classes will amount to less than one mile.

I intend after the definite completion of the measurements to communicate to the Society a list of the observed velocities, and will remark in conclusion that the velocities of the stars have proved to be much smaller than was to be expected from the direct observations. The mean result for forty-seven stars is 10·6 English miles.

Among them six have a velocity less than 2, and five greater than 20 miles; the greatest is that of *α Tauri*, about 30 miles. Fifteen of the stars have a positive and thirty-two a negative motion.

Potsdam, Royal Observatory:
1891 *December.*

The Motion of Σ 2525. By S. W. Burnham, M.A.

For some years this has been a difficult pair to measure. When it was discovered and first measured by Struve in 1830, it could be readily seen with the smallest instrument ordinarily used in double-star work. Since that time the distance has gradually lessened, and for the past few years only the largest refractors can separate the components. Until recently the change has been principally in distance, and all the measures made during the first fifty years are well represented by rectilinear motion. Notwithstanding that these positions appear to represent the movement of one star passing another from proper motion, the chances are greatly in favour of a physical relation between them.

I have made a set of measures of this pair with the 36-inch equatoreal under very favourable atmospheric conditions. Although the distance between the components is less than 0″·2, it is easy enough with this instrument, since it is well separated with medium powers, and the measures should have a good degree of accuracy.

The results found on the several nights are as ollows:—

1891·326	343°·7	0″·20	8·0 . . . 8·1
·389	343·4	0·17	8·0 . . . 8·2
·427	163·7	0·17	8·0 . . . 8·5
·449	342·7	0·17	8·0 . . . 8·1
1891·40	343·4	0·18	

In very close pairs of this kind, and particularly when the relative motion is not well understood, it is important to assign the proper quadrant to the smaller star. In the first three measures the angles were set down as above with no thought of the earlier observations, with a note, "quadrant certain," in the second measure. On the following night the angle was reversed, and on the last night the smaller component seemed to be on the preceding side, although the difference in the magnitudes was very small. The magnitudes in Struve are 7·4 and 7·6.

In order to determine this question more certainly, if possible, I examined the pair again on several nights, with the following results:

1891·485. Not very good seeing, but the smaller star appears to be in 160°.

1891·540. The stars are so nearly equal that it is impossible to tell with certainty which is the smaller. Well separated.

1891·578. The preceding star appears to be certainly the smallest, but the difference is perhaps not more than 0·1 or 0·2 of a magnitude. Splendid seeing.

The quadrant, therefore, is still uncertain, but the weight of the evidence, from my own observations, seems to be in favour of the position-angle being as given in the mean result of the several measures, and not 163°·4; but the latter seems to be more in harmony with the earlier observations. This can probably be definitely settled by the observations of next year. If the angle is what I have assumed it to be, then the angular movement has been 270° since 1830, and we should have sufficient data for an approximate determination of the period. On the other hand, if this position belongs in the opposite quadrant, then all the measured positions lie substantially in a straight line, and it would be impossible to say from this evidence alone whether the relative change is due to proper or orbital motion.

In the interest of a future investigation, I have collected from original sources, and arranged in chronological order, all the micrometrical observations of this pair, and give them here:—

Measures of Σ 2525.

		°	"		
1	1830·43	255·9	1·33	Σ.	5n
2	1836·14	255·5	1·30	Σ.	2n
3	1840·62	255·5	...	Da.	1n
	1840·70	252·4	1·28	OΣ.	2n
4	1842·41	251·0	0·82	Ma.	1n
5	1843·69	254·0	0·95	Ma.	1n
6	1854·63	246·8	1·05	OΣ.	1n
7	1856·61	247·1	0·85	Se.	2n
8	1865·22	240·9	0·60	Δ.	7n
9	1865·48	73·6	0·73	En.	2n
10	1865·64	239·9	0·40	Se.	1n
11	1865·76	241·5	0·74	OΣ.	2n
12	1872·61	234·0	0·66	OΣ.	1n
	1873·54	241·1	...	Ferr.	1n
13	1873·61	233·4	0·6	Δ	4n
	1873·65	232·1	...	WS.	3n
14	1874·84	234·3	0·48	Gl.	1n
15	1875·66	233·6	...	WS.	1n
	1875·65	232·1	0·45	Sp.	5n
16	1877·01	230·1	0·37	Sp.	5n
	1877·82	238·0	...	Δ	1n
17	1879·71	213·2	0·33	Hl.	3n
	1879·79	243·0	...	Do.	3n
18	1880·67	217·8	0·32	Sp.	6n

18	1880·71	210°·0	" . .	Do.	2n
19	1883·26	47·9	0·23	En.	8n
20	1883·63	200·0	0·35	Sp.	4n
	1883·58	Elong. 27°		Per.	[illegible]
21	1886·92	208·6	0·2 ±	Sp.	2n
	1887·71	Single		Sp.	4n
22	1891·40	343·4	0·18	β	4n

All of the measures in the foregoing list which are complete, twenty-two in number, are laid off to scale on the accompanying diagram as accurately as possible, and show at a glance all of the observed positions of this pair. The measures of 1891 are shown by outline circles in both quadrants. The successive measures are connected by lines, so that any one of them can be readily identified in the tabular list.

The resemblance between this pair and 20 *Draconis* is very striking, not only in the general direction of the components with reference to each other and their relative motions, but in the direction of the apparent movement of the respective companions. This will be very apparent by comparing the present diagram with that of 20 *Draconis* given in my paper on that pair in *Monthly Notices* for June 1891. The apparent relative motion of Σ 2525 is in the direction of about 83°, while that of 20 *Draconis*, as I have previously shown, is in the direction of 73°. Assuming that these are binary pairs—as is most probably the case—it is obvious that the apparent ellipses must be extremely elongated, and that the periods are of long duration. In a few years more,

doubtless, we shall have data for a better determination of these points.

The place of this star (1880) is:

R.A. $19^h\ 21^m\ 40^s$
Decl. $+27°\ 5'$

Mount Hamilton:
1891 *October* 31.

Note on some apparently variable Nebulæ.
By J. L. E. Dreyer, Ph.D.

In his ninth list of new nebulæ found at the Warner Observatory (*Astr. Nachr.*, No. 3004), Mr. Lewis Swift gave under No. 13 the following position (for 1890) and description of a nebula:

1889 December 23 $3^h\ 36^m\ 6^s$ $95°\ 2'{\cdot}1$ – *ee*F, *p*L, R, 1st of 3 in line with 1417–18, cometary. Unable to refind it; seeing good. Failed also at Harvard College Observatory.

In No. 3014 of the same journal Mr. Swift remarks about this object: "I strongly suspect it to have been a comet, as at two subsequent examinations it could not be found. It was in line with N.G.C. 1417 and 1418, and all three were seen simultaneously."*

From an examination of all the observations of nebulæ in the region in question, it appears to me to be more likely that we have here to do with a variable nebula and not with a comet. The following positions are all reduced to 1860:

Sir William Herschel.

	h	m	s	°	′		
III. 569	3	32	54	95	7		eF, *l*E, *er*
II. 455	3	34	59	95	8		Two, the *p* one *p*B, *c*L, E, *lb*M, the *f* one *e*F, *e*S, E
II. 456	3	35	26	95	9		

Sir John Herschel.

h 305	3	34	32·5	95	7 ±		No descr. 1st of 3 (one observation).
h 306	3	34	41·4	95	8	48	R, *np* a ✱, 2nd of 3 (one obs.).
h 307	3	35	1·8	95	9	36	*p*B, S, B ✱ 1′ *sf* (3 obs.).

d'Arrest.

III. 569	3	32	49·0	95	7	18	(2 obs.)
II. 455	3	35	0·5	95	9	28	(6 obs.)
II. 456	3	35	19·0	95	11	10	(3 obs.)

In the General Catalogue Sir John Herschel has only made use of his own observations, assuming III. 569 = *h* 305. That this was erroneous was pointed out by d'Arrest, whose positions of the three nebulæ agreed well with those determined by Sir W. Herschel. As I had also at Birr Castle in 1875–77 four times observed these three objects (and seen no others near them), and found their relative positions to be as indicated by d'Arrest, I adopted these in the New General Catalogue.

I had, however, when preparing the observations of nebulæ made with Lord Rosse's telescope for publication, been considerably puzzled at finding several observations from the years 1848–56, according to which there seemed to be a nebula nearly in the place of *h* 305. These observations are as follows:

1848 December 19.—3 neb. nearly in a line *nnp*.* Middle one the brightest, 2 others F. From 1st to 2nd about 10′, from 2nd to 3rd about 6′.

1850 October 7.—1st appears divided, and *p* part has a minute * or stellar point in it; 2nd about 11′ off is brightest of the 3 and *b*M; 3rd about 7′ from 2nd is equable in light, and I suspect a fourth F one perhaps 20′ off [G.C. 763].

1850 December 8.—1st is *v*F, and has a S * *np*; 2nd has, I suspect, a F Nucl; it is *b*M, and the brightest of the 3, s of a *. About 16′ *f* the third is a F Nova [G.C. 763].

1851 January 22.—1st *ee*F, divided ? * in *p* part; 2nd 9′ *sf*, centre *r* ? Brightest of them. 3rd 4′ *sf* 2nd and 14′ *f* is one, *v*F, E.

1855 December 13.—Found only *h* 306 and 307 . . .

1856 December 26.—*p* one is *v*F, mottled; 2nd is *p*B, E*np sf*, *b*MN; the 3rd is *v*F, *l*E ? no Nucl.

But in 1872, 1875, and three times in 1877 only *h* 306, *h* 307, and G.C. 763 were seen. The last observation (1877, December 6) I took for the special purpose of seeing whether there was a nebula 8′ or 10′ north preceding *h* 306, but as I could only see III. 569, 33′ preceding *h* 306, I concluded that the observers in 1848–56, who used Sir J. Herschel's Catalogue of 1833 as a working list, had been influenced by the relative positions in that Catalogue when estimating the distance between the first two nebulæ.

Now, however, the matter assumes a different aspect after Mr. Swift's observation. His position of the object seen in December 1889 is for 1860—

$$3^{h}\ 34^{m}\ 37^{s} \qquad 95^{\circ}\ 8'{\cdot}0$$

or 6′·2 north preceding II. 455, with which and with II. 456 it was seen in a straight line. This position agrees well with that

* *nnp* should, no doubt, be *npp*.

determined by Sir John Herschel (*h* 305), as well as with the place given by the Birr Castle observers in 1848–56. This very faint nebula would seem to have been visible in 1827, 1848, 1850, 1851, 1856, and 1889, while it was not seen in 1785, 1855, 1864, 1865, 1872, 1875, 1877, and 1890. It is, however, important to remember that it was only *specially looked for* in 1877 and 1890, though d'Arrest probably also looked specially in the place given by Sir J. Herschel for *h* 305.

Observers of nebulæ are accustomed occasionally to find a particular object very difficult to see owing to atmospheric causes, but the present case is certainly a very suspicious one, and the region 6′ north preceding the nebula II. 455=N.G.C. 1417 should therefore be watched from time to time with powerful instruments. II. 455 and 456 are easily recognised, as they form a trapezium with two stars of 11th or 12th magnitude south following.

Some years ago Professor Winnecke drew attention to two nebulæ which he suspected of periodic variability, *h* 229 and *h* 882.* The former was invisible (or perhaps barely visible) to Schönfeld in December 1861 ($6\frac{1}{2}$-inch refractor), and invisible to Vogel on two nights in November 1865 ($8\frac{1}{2}$-inch refractor), while all other observers (including Schönfeld in 1864) called it *p*B, or of the second class. In November 1887 I noted it as "fully of the second class," and in December 1888 as "perhaps barely of the second class." The evidence of variability does not seem very strong in this case. As regards *h* 882, the variability seems scarcely better established. Great weight cannot be attached to the circumstance that Boguslawski (using a $3\frac{1}{2}$-inch refractor) inserted it as bright on the Berlin map (*Hora XI.*), as he very possibly merely did so because it had been rated as a first-class nebula by W. Herschel. On May 24, 1887, I looked it up, but "could only just see it, and should certainly not have found it but for the star 6th mag. *nf*; twilight and strong haze." This observation is, however, of very little value, but on March 30, 1891, I found it "*p*B, though perhaps barely of the second class," and on April 8, 1891, "*p*B, good to observe" [with bright wire illumination]. This agrees with J. Herschel's, d'Arrest's, and Winnecke's estimates, and the suspicion of variability rests almost entirely on the fact that J. Herschel, in 1830, found it "*e*F, 2nd or 3rd class." It should be remembered that this is a diffused nebula with very slight central condensation, and, as far as my experience goes, the appearance of objects of this kind is far more influenced by the state of our atmosphere than that of nebulæ with a distinct condensation generally is.

In the notes to the General Catalogue (p. 32), Sir J. Herschel suggests that a change may have occurred in the nebula I 41=*h* 1452. "On April 5,† 1784, H. describes it as L, B, *r*,

* *Monthly Notices*, xxxviii. p. 104, *Astron. Nachr.*, No. 2293.

† Should be April 25 according to Caroline Herschel's copy of the sweeps in the Society's library.

*sb*M,* *i*R figure, Class I.; on March 3,† 1789, *p*B, *c*L, *i* Fig., *er*, many of the stars visible, so that it may be called a cluster." J. Herschel and d'Arrest estimated it as belonging to the third class. I observed it twice in May 1891, and found it "F, *p*L, diffused, perhaps double or with *v*F star involved south, very little or no condensation, irregular figure, barely second class." This is another case of an uncondensed nebula, and there does not seem any reason to think it variable. I may mention that the right ascension (according to *h*) adopted in the N. G. C. is correct, the nebula being 18^s following and $3'\cdot9$ north of the star *Munich* 8551.

In the *Astr. Nachr.*, No. 1520, d'Arrest announced that a small object stated by Schmidt to be 5^s preceding and 6′ south of M 49 (*h* 1294) could not be seen by him, and that only two very small stars appeared in the place. As nothing has been seen in the place in question by any other observer, there seems no reason to assume that a nebula ever existed there. W. Herschel's II. 498 cannot have been the same as Schmidt's object, as H. would no doubt have pointed out that it was between II. 18 and M 49; and II. 498 is therefore beyond a doubt = II. 18.

Whatever view we take of the nature of nebulæ, the question whether these objects vary in brightness must be considered as one of paramount importance. It is for this reason that I have thought it desirable to call attention to Mr. Swift's nebula; but it is with some reluctance that I have done so, as the greatest possible caution is necessary in deciding whether any change has really taken place in objects of this class. The lessons taught us by the satellite of *Venus* and the intra-mercurial planets ought to be kept well in mind when we feel inclined to draw important conclusions from very uncertain observations, which may admit of a different interpretation.

Note on the Variability of Es-Birm 673 = D.M. + 39°·4208.
By the Rev. T. E. Espin, B.A.

This star is No. 118 of my list of "Some New Red and Orange-red Stars," *Monthly Notices*, xlvi. No. 5, p. 293. The brightness on the night of its discovery (1885 July 9) was 7·9, and it irregularly diminished to 9·0. Since this time it has been occasionally observed, and found to be practically invariable up to the present year. On comparing some of Dr. Wolf's photographs together I was struck by the differences in the magnitudes of this star. The colour is fine red, and consequently

* C. H. has "*lb*M," an important difference.
† C. H. has March 23.

the star is from two to three magnitudes fainter on the photographs. There are several small stars near, and on the night of November 19 their magnitudes were roughly estimated. The star is found on three of Dr. Wolf's photographs that he has kindly sent me. The third photograph is not dated, but, I believe, was taken in the beginning of November. The following are the magnitudes taken from the photographs:

1891 June 1	10·8
September 9 and 10	11·2
November	10·0

On November 19 the star was estimated as 7·6, and on November 26 as 7·8.

Tow Law, Darlington:
1891 *December* 9.

Note on the Stonyhurst Drawings of the Solar Spots and Faculæ.
By the Rev. Walter Sidgreaves.

At the commencement of the series of Sun-spot drawings, instituted by the late Fr. Perry in November 1880, it was decided to fill in the faculæ. so far as this could be done with certainty. No small difficulty was experienced in the attempt, for it seemed impossible to produce a faithful representation of them, and both the director and the observer were forced to be content with a skeleton tracing of the brighter parts which could be differentiated from the rest of the photosphere without chance of error. Experience, however, in the course of time, taught the observer the magic effect of motion imparted to a faint image; and as he slowly travelled the image of the Sun across the drawing-sheet, the patches stood out with a clearness of definition that excluded all doubt of the border-line between faculæ and photospheric glare. The method then adopted, and followed ever since, was first to outline the brighter parts upon the stationary image, and then to fill in the picture by sketching the fainter details taken from the image while moving it slowly to and fro across the paper. By this means a very trustworthy record was obtained; and it was much improved by adopting the suggestion, made by Sir G. Stokes in 1883, that the contrast of a red-lead tracing of the faculæ would greatly help the eye in its search through the drawings for the true relation between the dark spots and their glowing attendants. This is apparent in following the disturbances through all their changes, and in sifting their evidences for an answer to the query, Which is the forerunner of the other?

During the entire period of Fr. Perry's direction of this observatory no clear instance of faculæ preceding the birth of a spot had been detected in the drawings. Faculæ were always most abundant after the birth of a spot, and always outlived it, lingering for weeks and sometimes for months before expiring. But, on the other hand, the drawings afford no positive evidence of the birth of a spot before the appearance of faculæ; while every spot of importance appears to have been attended from the beginning with at least a small surrounding of faculæ. So that, although it remains true that faculæ in no extensive form precede the birth of a spot, but develop and grow to maturity either along with the spot or after its decline, we must guard our conclusions against their extension to the absolute priority of the spot.

The chances of gaining the positive evidence about the priority are not favourable. The greater part of the Sun's surface, on which a spot may spring into life, offers no possibility of seeing the faculæ. And during the years of greater activity our chances are greatly reduced by the interlacing of old and new faculæ. It is only during the minimum period of spot-life, when the intervals are greater and old *débris* get cleared away before new storms begin, that we can well hope for the evidence we want.

The drawings of the recent minimum period of 1889 have been under careful study during the past twelve months, and we find amongst them two cases in which the evidence of first appearance is unquestionable. And both of these show faculæ before any trace of a spot appears.

On June 29 a small patch of faculæ was sketched near the eastern limb, in latitude $-40^\circ\,5$ and in longitude 252°. There was no trace of a spot in the neighbourhood, and neither spot nor faculæ had been seen near the position for years. On the following day a small round spot appeared in latitude $-40^\circ{\cdot}3$ and longitude $252^\circ{\cdot}2$—*i.e.*, in the midst of the faculæ, the faculæ on this day being visible only just close round the spot. Again, on July 31, another small patch of faculæ appeared in latitude -22°, longitude 155°, without any spot near it. It was seen again on the following day, and still without a spot. But on the third day, August 2, a spot was sketched in latitude $-21^\circ{\cdot}9$, longitude $155^\circ{\cdot}4$.

In both cases the faculæ were of small area, but bright. And there can be no doubt either of the faculæ or of the spots. Both were new. The faculæ were not remnants, and the spots were not revivals of old disturbances. We may not be able yet to conclude that faculæ are really forerunners of spots. The two spots referred to may have been for the time hidden from our view by the faculæ. But this has no appearance of probability, the faculæ being seen at a distance from the limb of quite one-tenth of the solar diameter. So far, therefore, as our drawings at these dates are witnesses to priority, their evidence stands for

some faculæ preceding the birth of a spot. And more of the same class of evidence may be found even in the years of greater spot frequency, when the records of their spots and faculæ have been more fully examined and the history of each group is more accurately written.

Stonyhurst Observatory,
Lancashire.

On the Determination of Azimuth by Elongations of Polaris.
By Harold Jacoby, B.A.

When Polaris has been observed within half an hour of elongation for the determination of azimuth, the "reduction to elongation" is frequently computed by the formulæ:

$$m = \frac{2 \sin^2 \frac{1}{2} (t_e - t)}{\sin 1''}$$

$$a_e - a = a_e \,.\, m \,.\, \sin 1''$$

where

t_e, a_e, are the hour angle and azimuth of *Polaris* at elongation,

t, a, " " " " the observation,

a_e and a being reckoned in seconds of arc, from the north point.

But we can avoid the use of the somewhat extended table for m by tabulating $a_e - a$ itself. For if we put

$$M = 6000 \sin 1'' \cdot m$$

$$f = \frac{a_e - 6000}{6000}$$

we shall have

$$a_e - a = M + fM$$

Table I. gives M, with the argument $t_e - t$; and Table II. gives f with the argument a_e. It will be seen that M is really an approximate value of $a_e - a$, and f a correction factor for M. This factor can be multiplied by M with Crelle's Tables, so that logarithms will not be required.

Table III. gives the values of a_e and t_e for all latitudes between 35° and 55°. It is intended to take the place of the logarithmic calculation of a_e and t_e, or at least to serve as a check. The columns headed A and T are computed with the declination 88° 45′ 0″, and furnish approximate values of a_e and t_e. The columns headed x and y give the variations, per second of δ, of the azimuth and hour angle. We shall have, therefore,

$$a_e = A + x(\delta - 88^\circ\ 45')$$

$$t_e = T + y(\delta - 88^\circ\ 45')$$

where $\delta - 88° 45'$ is to be expressed in seconds of arc. These formulæ will give a_e and t_e with all necessary accuracy for many years.

The following observations, made by one of the students of the Summer School in Geodesy of Columbia College, will serve to illustrate the use of the tables. The data employed are—

Station: New London, New Hampshire, No. 3.
Date: 1891 July 13.
Longitude: 71° 59′ West.
Latitude: 43° 24′·0.
Polaris $a = 1^h\ 18^m\ 49^s{\cdot}6$. $\delta = 88°\ 43'\ 23''{\cdot}1$.

We have then

$$\delta - 88°\ 45' = -96''{\cdot}9,$$

and, from Table III.,

$$\text{for } \phi = 43°\ 24'{\cdot}0$$

	A = 1° 43′ 13″·89, $x = -1''{\cdot}3766$,	T =	5ʰ 55ᵐ 16ˢ·3, $y = +{\cdot}0631$ˢ
$x(\delta - 88°\ 45')$	= +2 13·39,	$y(\delta - 88°\ 45')$ =	— 6·1
a_e	= 1 45 27·28,	t_e =	5 55 10·2
		a =	1 18 49·6
Sidereal Time of Elongation ...	...	... =	19 23 39·4

The values here obtained for a_e and t_e are the same as would be given by a logarithmic calculation. The observations of Polaris were (eastern elongation):

No.	Pos.	Sidereal Time. h m s	Corrected Readings. ° ′ ″	$t_e - t$ m s	M Table I. ″	fM Table II. ″	$a_e - a$ ″	Reduced Readings. ° ′ ″
1	D	18 56 1·3	39 37 22·1	27 38·1	43·57	2·40	45·97	39 38 8·1
2	...	18 59 18·8	27·5	24 20·6	33·83	1·86	35·69	38 3·2
3	...	19 9 11·4	41·0	14 28·0	11·95	0·66	12·61	37 53·6
4	...	19 11 20·8	56·0	12 18·6	8·67	0·48	9·15	38 5·2
5	R	19 20 26·3	219 37 43·9	3 13·1	0·59	0·03	0·62	219 37 44·5
6	...	19 23 11·7	38·5	0 27·7	0·01	0·00	0·01	38·5
7	...	19 27 24·4	32·1	3 45·0	0·81	0·04	0·85	33·0
8	...	19 29 17·7	29·2	5 38·3	1·81	0·10	1·91	31·1
9	...	19 33 49·5	33·7	10 10·1	5·90	0·32	6·22	39·9
10	...	19 37 4·0	18·6	13 24·6	10·28	0·57	10·85	29·4
11	...	19 41 0·6	16·8	17 21·2	17·19	0·95	18·14	34·9
12	...	19 45 0·3	7·3	21 20·9	26·02	1·43	27·45	34·8

The above observations are discordant, but they show how the tables are used.

TABLE I.

M.

m	0ˢ	10ˢ	20ˢ	30ˢ	40ˢ	50ˢ	Difference for 10ˢ
	″	″	″	″	″	″	″
0	0·00	0·00	0·01	0·01	0·03	0·04	0·01
1	0·06	0·08	0·10	0·13	0·16	0·19	0·03
2	0·23	0·27	0·31	0·36	0·41	0·46	0·05
3	0·51	0·57	0·64	0·70	0·77	0·84	0·07
4	0·91	0·99	1·07	1·16	1·24	1·34	0·09
5	1·43	1·52	1·62	1·73	1·83	1·94	0·10
6	2·06	2·17	2·29	2·41	2·54	2·67	0·12
7	2·80	2·93	3·07	3·21	3·36	3·50	0·14
8	3·66	3·81	3·97	4·13	4·29	4·46	0·16
9	4·63	4·80	4·98	5·15	5·34	5·52	0·18
10	5·71	5·90	6·10	6·30	6·50	6·70	0·20
11	6·91	7·12	7·34	7·55	7·77	8·00	0·22
12	8·22	8·46	8·69	8·92	9·16	9·41	0·24
13	9·65	9·90	10·15	10·41	10·67	10·92	0·26
14	11·19	11·47	11·73	12·00	12·28	12·57	0·28
15	12·85	13·14	13·43	13·72	14·02	14·32	0·29
16	14·62	14·92	15·23	15·54	15·86	16·18	0·31
17	16·50	16·83	17·16	17·49	17·82	18·16	0·33
18	18·50	18·85	19·19	19·54	19·89	20·25	0·35
19	20·61	20·97	21·34	21·71	22·08	22·46	0·37
20	22·83	23·21	23·60	23·99	24·39	24·78	0·39
21	25·18	25·58	25·98	26·39	26·80	27·21	0·41
22	27·64	28·05	28·47	28·90	29·33	29·76	0·43
23	30·19	30·63	31·08	31·52	31 97	32·42	0·45
24	32·88	33·34	33·80	34·26	34·73	35·20	0·46
25	35·67	36·15	36·63	37·11	37·59	38·08	0·48
26	38·58	39·08	39·58	40·08	40·58	41·09	0·50
27	41·60	42·11	42·63	43·15	43·67	41·20	0·52
28	44·73	45·27	45·81	46·34	46·88	47·42	0·54
29	47·97	48·53	49·09	49·65	50·21	50·77	0·56

TABLE II.

f.

a_e Az. at Elong.	f. Corr. Factor.	a_e Az. at Elong.	f Corr. Factor.
° ′		° ′	
1 20	−0·200	2 0	+0·200
1 30	−0·100	2 10	+0·300
1 40	0·000	2 20	+0·400
1 50	+0·100		

TABLE III.

ϕ Latitude.	A Azimuth at Elongation.	x Var. of Azimuth for 1″ of δ.	T Hour Angle at Elongation.	y Var. of Hour Angle for 1″ of δ.
° ′	° ′ ″	″	h m s	s
35 0	1 31 33·70	−1·2210	5 56 29·9	+·0467
	11·24	24	1·3	3
10	1 31 44·94	−1·2234	5 56 28·6	+·0470
	11·33	26	1·3	3
20	1 31 56·27	−1·2260	5 56 27·3	+·0473
	11·43	25	1·3	3
30	1 32 7·70	−1·2285	5 56 26·0	+·0476
	11·52	26	1·3	3
40	1 32 19·22	−1·2311	5 56 24·7	+·0479
	11·61	25	1·4	3
50	1 32 30·83	−1·2336	5 56 23·3	+·0482
	11·71	26	1·3	3
36 0	1 32 42·54	−1·2362	5 56 22·0	+·0485
	11·81	27	1·3	3
10	1 32 54·35	−1·2389	5 56 20·7	+·0488
	11·90	26	1·4	3
20	1 33 6·25	−1·2415	5 56 19·3	+·0491
	12·01	27	1·4	3
30	1 33 18·26	−1·2442	5 56 17·9	+·0494
	12·10	27	1·3	3
40	1 33 30·36	−1·2469	5 56 16·6	+·0497
	12·20	27	1·3	3
50	1 33 42·56	−1·2496	5 56 15·3	+·0500
	12·31	27	1·4	3
37 0	1 33 54·87	−1·2523	5 56 13·9	+·0503
	12·40	28	1·4	3
10	1 34 7·27	−1·2551	5 56 12·5	+·0506
	12·51	28	1·4	3
20	1 34 19·78	−1·2579	5 56 11·1	+·0509
	12·61	28	1·4	3
30	1 34 32·39	−1·2607	5 56 9·7	+·0512
	12·73	28	1·4	3
40	1 34 45·12	−1·2635	5 56 8·3	+·0515
	12·81	28	1·3	3
50	1 35 57·93	−1·2663	5 56 7·0	+·0518
	12·93	29	1·4	3
38 0	1 35 10·86	−1·2692	5 56 5·6	+·0521
	13·04	29	1·5	3
10	1 35 23·90	−1·2721	5 56 4·1	+·0524
	13·14	29	1·4	3
20	1 35 37·04	−1·2750	5 56 2·7	+·0527
	13·25	30	1·4	4
30	1 35 50·29	−1·2780	5 56 1·3	+·0531
	13·37	29	1·4	3
40	1 36 3·66	−1·2809	5 55 59·9	+·0534
	13·47	31	1·4	3
50	1 36 17·13	−1·2840	5 55 58·5	+·0537
	13·59	30	1·5	3

Azimuth at Elongation $= A + x(\delta - 88° 45')$. Hour Angle at Elongation $= T + y(\delta - 88° 45')$. $(\delta - 88° 45')$ to be expressed in seconds of arc.

ϕ Latitude.	A Azimuth at Elongation.	x Var. of Azimuth for 1″ of δ.	T Hour Angle at Elongation.	y Var. of Hour Angle for 1″ of δ.
° ′	° ′ ″	″	h m s	s
39 0	1 36 30·72	−1·2870	5 55 57·0	+·0540
	13·70	30	1·5	4
10	1 36 44·42	−1·2900	5 55 55·5	+·0544
	13·82	31	1·4	3
20	1 36 58·24	−1·2931	5 55 54·1	+·0547
	13·92	31	1·4	3
30	1 37 12·16	−1·2962	5 55 52·7	+·0550
	14·05	31	1·5	3
40	1 37 26·21	−1·2993	5 55 51·2	+·0553
	14·17	32	1·5	3
50	1 37 40·38	−1·3025	5 55 49·7	+·0556
	14·28	32	1·5	4
40 0	1 37 54·66	−1·3057	5 55 48·2	+·0560
	14·40	32	1·5	3
10	1 38 9·06	−1·3089	5 55 46·7	+·0663
	14·53	32	1·5	3
20	1 38 23·59	−1·3121	5 55 45·2	+·0566
	14·65	32	1·5	4
30	1 38 38·24	−1·3153	5 55 43·7	+·0570
	14·76	33	1·5	3
40	1 38 53·00	−1·3186	5 55 42·2	+·0573
	14·90	33	1·5	3
50	1 39 7·90	−1·3219	5 55 40·7	+·0576
	15·02	34	1·6	4
41 0	1 39 22·92	−1·3253	5 55 39·1	+·0580
	15·14	33	1·5	3
10	1 39 38·06	−1·3286	5 55 37·6	+·0583
	15·28	34	1·5	4
20	1 39 53·34	−1·3320	5 55 36·1	+·0587
	15·40	34	1·6	3
30	1 40 8·74	−1·3354	5 55 34·5	+·0590
	15·53	35	1·6	4
40	1 40 24·27	−1·3389	5 55 32·9	+·0594
	15·67	35	1·5	3
50	1 40 39·94	−1·3424	5 55 31·4	+·0597
	15·80	35	1·6	4
42 0	1 40 55·74	−1·3459	5 55 29·8	+·0601
	15·93	36	1·6	3
10	1 41 11·67	−1·3495	5 55 28·2	+·0604
	16·07	35	1·5	4
20	1 41 27·74	−1·3530	5 55 26·7	+·0608
	16·20	36	1·6	3
30	1 41 43·94	−1·3566	5 55 25·1	+·0611
	16·35	37	1·7	4
40	1 42 0·29	−1·3603	5 55 23·4	+·0615
	16·48	36	1·6	3
50	1 42 16·77	−1·3639	5 55 21·8	+·0618
	16·63	37	1·6	4

Azimuth at Elongation $= \mathrm{A} + x(\delta - 88^\circ\,45')$. Hour Angle at Elongation $= \mathrm{T} + y(\delta - 88^\circ\,45')$. $(\delta - 88^\circ\,45')$ to be expressed in seconds of arc.

ϕ Latitude.	A Azimuth at Elongation.	x Var. of Azimuth for 1″ of δ.	T Hour Angle at Elongation.	y Var. of Hour Angle for 1″ of δ.
° ′	° ′ ″	″	h m s	s
43 0	1 42 33·40	−1·3676	5 55 20·2	+·0622
	16·77	37	1·7	4
10	1 42 50·17	−1·3713	5 55 18·5	+·0626
	16·91	38	1·6	3
20	1 43 7·08	−1·3751	5 55 16·9	+·0629
	17·06	38	1·6	4
30	1 43 24·14	−1·3789	5 55 15·3	+·0633
	17·20	38	1·7	4
40	1 43 41·34	−1·3827	5 55 13·6	+·0637
	17·36	39	1·7	3
50	1 43 58·70	−1·3866	5 55 11·9	+·0640
	17·50	39	1·7	4
44 0	1 44 16·20	−1·3905	5 55 10·2	+·0644
	17·65	39	1·7	4
10	1 44 33·85	−1·3944	5 55 8·5	+·0648
	17·81	40	1·7	4
20	1 44 51·66	−1·3984	5 55 6·8	+·0652
	17·97	40	1·7	4
30	1 45 9·63	−1·4024	5 55 5·1	+·0656
	18·12	40	1·7	4
40	1 45 27·75	−1·4064	5 55 3·4	+·0660
	18·28	41	1·7	3
50	1 45 46·03	−1·4105	5 55 1·7	+·0663
	18·44	41	1·8	4
45 0	1 46 4·47	−1·4146	5 54 59·9	+·0667
	18·60	41	1·7	4
10	1 46 23·07	−1·4187	5 54 58·2	+·0671
	18·76	42	1·8	4
20	1 46 41·83	−1·4229	5 54 56·4	+·0675
	18·93	42	1·7	4
30	1 47 0·76	−1·4271	5 54 54·7	+·0679
	19·10	42	1·8	4
40	1 47 19·86	−1·4313	5 54 52·9	+·0683
	19·26	43	1·8	4
50	1 47 39·12	−1·4356	5 54 51·1	+·0687
	19·44	43	1·8	4
46 0	1 47 58·56	−1·4399	5 54 49·3	+·0691
	19·60	44	1·3	4
10	1 48 18·16	−1·4443	5 54 47·5	+·0695
	19·79	44	1·9	4
20	1 48 37·95	−1·4487	5 54 45·6	+·0699
	19·95	44	1·8	4
30	1 48 57·90	−1·4531	5 54 43·8	+·0703
	20·14	45	1·9	4
40	1 49 18·04	−1·4576	5 54 41·9	+·0707
	20·32	45	1·8	4
50	1 49 38·36	−1·4621	5 54 40·1	+·0711
	20·50	46	1·9	4

Azimuth at Elongation $= A + x(\delta - 88^\circ\ 45')$. Hour Angle at Elongation $= T + y(\delta - 88^\circ\ 45')$. $(\delta - 88^\circ\ 45')$ to be expressed in seconds of arc.

ϕ Latitude.	A Azimuth at Elongation.	x Var. of Azimuth for 1″ of δ.	T Hour Angle at Elongation.	y Var. of Hour Angle for 1″ of δ.
° ′	° ′ ″	″	h m s	s
47 0	1 49 58·86	−1·4667	5 54 38·2	+·0715
	20·68	46	1·9	5
10	1 50 19·54	−1·4713	5 54 36·3	+·0720
	20·87	46	1·9	4
20	1 50 40·41	−1·4759	5 54 34·4	+·0724
	21·06	47	1·9	4
30	1 51 1·47	−1·4806	5 54 32·5	+·0728
	21·25	48	1·9	4
40	1 51 22·72	−1·4854	5 54 30·6	+·0732
	21·45	47	1·9	4
50	1 51 44·17	−1·4901	5 54 28·7	+·0736
	21·63	48	2·0	5
48 0	1 52 5·80	−1·4949	5 54 26·7	+·0741
	21·84	49	1·9	4
10	1 52 27·64	−1·4998	5 54 24·8	+·0745
	22·03	49	2·0	5
20	1 52 49·67	−1·5047	5 54 22·8	+·0750
	22·24	49	2·0	4
30	1 53 11·91	−1·5096	5 54 20·8	+·0754
	22·44	50	2·0	4
40	1 53 34·35	−1·5146	5 54 18·8	+·0758
	22·65	51	2·0	5
50	1 53 57·00	−1·5197	5 54 16·8	+·0763
	22·86	51	2·0	4
49 0	1 54 19·86	−1·5248	5 54 14·8	+·0767
	23·07	51	2·1	5
10	1 54 42·93	−1·5299	5 54 12·7	+·0772
	23·28	52	2·0	4
20	1 55 6·21	−1·5351	5 54 10·7	+·0776
	23·51	52	2·1	5
30	1 55 29·72	−1·5403	5 54 8·6	+·0781
	23·71	53	2·1	5
40	1 55 53·43	−1·5456	5 54 6·5	+·0786
	23·95	53	2·0	4
50	1 56 17·38	−1·5509	5 54 4·5	+·0790
	24·17	54	2·1	5
50 0	1 56 41·55	−1·5563	5 54 2·4	+·0795
	24·39	54	2·1	5
10	1 57 5·94	−1·5617	5 54 0·3	+·0800
	24·63	55	2·2	4
20	1 57 30·57	−1·5672	5 53 58·1	+·0804
	24·86	55	2·2	5
30	1 57 55·43	−1·5727	5 53 55·9	+·0809
	25·09	56	2·1	5
40	1 58 20·52	−1·5783	5 53 53·8	+·0814
	25·34	56	2·2	5
50	1 58 45·86	−1·5839	5 53 51·6	+·0819
	25·58	57	2·2	5

Azimuth at Elongation $= A + x(\delta - 88° 45')$. Hour Angle at Elongation $= T + y(\delta - 88° 45')$. $(\delta - 88° 45')$ to be expressed in seconds of arc.

ϕ Latitude.	A Azimuth at Elongation.	x Var. of Azimuth for 1″ of δ.	T Hour Angle at Elongation.	y Var. of Hour Angle for 1″ of δ.
° ′	° ′ ″	″	h m s	s
51 0	1 59 11·44	−1·5896	5 53 49·4	+·0824
	25·83	57	2·2	5
10	1 59 37·27	−1·5953	5 53 47·2	+·0829
	26·06	58	2·2	5
20	2 0 3·33	−1·6011	5 53 45·0	+·0834
	26·32	59	2·3	5
30	2 0 29·65	−1·6070	5 53 42·7	+·0839
	26·58	59	2·2	5
40	2 0 56·23	−1·6129	5 53 40·5	+·0844
	26·83	60	2·3	5
50	2 1 23·06	−1·6189	5 53 38·2	+·0849
	27·10	60	2·3	5
52 0	2 1 50·16	−1·6249	5 53 35·9	+·0854
	27·36	61	2·3	5
10	2 2 17·52	−1·6310	5 53 33·6	+·0859
	27·63	62	2·3	5
20	2 2 45·15	−1·6372	5 53 31·3	+·0864
	27·90	62	2·4	6
30	2 3 13·05	−1·6434	5 53 28·9	+·0870
	28·18	63	2·4	5
40	2 3 41·23	−1·6497	5 53 26·5	+·0875
	28·46	63	2·4	5
50	2 4 9·69	−1·6560	5 53 24·1	+·0880
	28·74	64	2·4	6
53 0	2 4 38·43	−1·6624	5 53 21·7	+·0886
	29·02	64	2·4	5
10	2 5 7·45	−1·6688	5 53 19·3	+·0891
	29·32	65	2·4	5
20	2 5 36·77	−1·6753	5 53 16·9	+·0896
	29·60	66	2·4	6
30	2 6 6·37	−1·6819	5 53 14·5	+·0902
	29·91	67	2·5	5
40	2 6 36·28	−1·6886	5 53 12·0	+·0907
	30·21	67	2·5	6
50	2 7 6·49	−1·6953	5 53 9·5	+·0913
	30·52	68	2·6	5
54 0	2 7 37·01	−1·7021	5 53 6·9	+·0918
	30·82	69	2·5	6
10	2 8 7·83	−1·7090	5 53 4·4	+·0924
	31·15	69	2·5	
20	2 8 38·98	−1·7159	5 53 1·9	+·0930
	31·46	70	2·6	5
30	2 9 10·44	−1·7229	5 52 59·3	+·0935
	31·78	70	2·6	6
40	2 9 42·22	−1·7299	5 52 56·7	+·0941
	32·11	72	2·6	6
50	2 10 14·33	−1·7371	5 52 54·1	+·0947
	32·45	74	2·7	6
55 0	2 10 46·78	−1·7443	5 52 51·4	+·0953

Azimuth at Elongation $= A + x(\delta - 88^\circ\ 45')$. Hour Angle at Elongation $= T + y(\delta - 88^\circ\ 45')$. $(\delta - 88^\circ\ 45')$ to be expressed in seconds of arc.

Columbia College, New York,
1891 *September* 30.

On the Reduction of Transit Observations by the Method of Least Squares. By Harold Jacoby, B.A.

When it is desired to adjust a series of observations by the method of least squares, the process usually employed is not always the most advantageous one available—in fact, the usual method is really an ingenious way of finding the *adjusted* values of the unknowns from the coefficients and absolute terms of the original observation equations. Occasionally, however, these coefficients are themselves all functions of some single quantity. In such a case there must exist a functional relation between the adjusted values of the unknowns and the single quantity in question; and this relation may possibly be evaluated *without computing the actual coefficients of the observation equations.* The above applies to the transit instrument in the meridian, for the coefficients of the observation equations, as well as the weight-factor, are then all functions of the declination. The *latitude* affects them as a constant only.

Before going into the details of the application of the above remarks to actual work, it is desirable to call attention to a theorem in the method of least squares which is very often of considerable use. Let there be given two groups of linear observation equations of the form:

$$
\begin{array}{ll}
a_1w + b_1y + c_1z + d_1 = 0, & a_1'x + b_1'y + c_1'z + d_1' = 0, \\
a_2w + b_2y + c_2z + d_2 = 0, & a_2'x + b_2'y + c_2'z + d_2' = 0, \\
\cdots\cdots & \cdots\cdots
\end{array}
$$

in which it will be seen that the equations of the first group lack the term in x, and those of the second group lack the term in w. Now let normal equations be formed from each group as follows:

$$
\begin{array}{rr}
[aa]w + [ab]y + [ac]z + [ad] = 0, & [a'a']x + [a'b']y + [a'c']z + [a'd'] = 0. \\
[bb]y + [bc]z + [bd] = 0, & [b'b']y + [b'c']z + [b'd'] = 0. \\
[cc]z + [cd] = 0, & [c'c']z + [c'd'] = 0, \\
[dd] & [d'd'].
\end{array}
$$

Let w and x be eliminated in the usual way, giving:

$$
\begin{array}{rr}
[bb.1]y + [bc.1]z + [bd.1] = 0, & [b'b'.1]y + [b'c'.1]z + [b'd'.1] = 0, \\
[cc.1]z + [cd.1] = 0, & [c'c'.1]z + [c'd'.1] = 0, \\
[dd.1] & [d'd'.1].
\end{array}
$$

Now let these equations be added, term by term, giving:

$$
\begin{array}{r}
([bb.1] + [b'b'.1])y + ([bc.1] + [b'c'.1])z + ([bd.1] + [b'd'.1]) = 0, \\
([cc.1] + [c'c'.1])z + ([cd.1] + [c'd'.1]) = 0, \\
([dd.1] + [d'd'.1]);
\end{array}
$$

then the equations last obtained are *identically* the same as would have resulted if we had formed a set of normal equations from the two original groups of observation equations, taken altogether as a single group, and then eliminated w and x according to the usual rule.*

When transit observations are reduced upon the assumption that the azimuth changed when the instrument was reversed,† we have two groups of observation equations of the kind just mentioned, and may take advantage of the above principle. It is, perhaps, out of place here to remark upon the desirability of making such an assumption, since the method to be given is equally applicable in any case. Perhaps the strongest argument against the use of a least square solution, upon the hypothesis of two values of the azimuth, is that the actual observation times of the reversal are in no way affected by the azimuth of the instrument before reversal, and ought therefore to have no influence in the determination of that quantity. It is certain, however, that they do obtain such an influence, if a least square adjustment is made upon the assumption of two azimuths. Yet the same objection will apply to observations of any kind in which some of the observation equations have one or more zero coefficients, a case occurring very frequently in practice. We have abundant authority for applying the method of least squares in such cases. It only remains to inquire whether the hypothesis of a change of azimuth is warranted by facts. Does such a change really occur? Upon this point no decisive evidence has been published, so far as I know. It must, therefore, be left to each observer to decide whether he has sufficient skill to reverse his instrument with a certainty of not appreciably changing the azimuth adjustment. If so, he would violate a known fact, by assuming that the azimuth changed in reversing. It seems, however, that in the majority of cases it is quite safe to assume two azimuths. It will be shown below that it is possible to make separate reductions on *both* hypotheses without very extensive extra calculations.

So much being premised, we can proceed to explain the proposed method of reduction, beginning with the process applicable to the hypothesis of *no change of azimuth*. If we assume the usual notation, we shall have, by Mayer's formula, for each observation a weighted equation of the form:

$$\sqrt{p}\,\mathrm{A}x \pm \sqrt{p}\,\mathrm{C}y + \sqrt{p}\,\mathrm{B}z + \sqrt{p}\,l = 0 \begin{cases} \text{Clamp West.} \\ \text{Clamp East.} \end{cases}$$

---

* For a demonstration of this interesting theorem, see *Jordan, Handbuch der Vermessungskunde, erster Band* (*Ausgleichungsrechnung*) *dritte Auflage*, 1888, p. 78.

† Chauvenet, *Spherical and Practical Astronomy*, vol. ii., p. 201. Doolittle, *Practical Astronomy*, p. 325.

in which, as usual:

$$A=\frac{\sin(\phi-\delta)}{\cos\delta},\ B=\frac{\cos(\phi-\delta)}{\cos\delta},\ C=\frac{1}{\cos\delta},\ p=\text{weight},$$

$$l=T-a\mp\Delta\theta_0+Aa_0+Bb\pm Cc_0-0^s\cdot021\cos\phi\sec\delta\begin{cases}\text{Clamp West,}\\\text{Clamp East,}\end{cases}$$

and $\Delta\theta_0$, a_0, and c_0 are approximate values of the chronometer correction, azimuth constant, and collimation constant.* After the solution has been carried out, we have as the adjusted values—

$$a=a_0+x,\ c=c_0+y,\ \Delta\theta=\Delta\theta_0+z.$$

Now let us write—

$$m_1=\pm p\sec\delta,\ m_2=\pm p\tan\delta\sec\delta,\ m_3=p,\ m_4=p\tan\delta,\ m_5=p\tan^2\delta,$$

$$m_6=p\sec^2\delta\begin{cases}\text{Clamp West,}\\\text{Clamp East,}\end{cases}$$

and put

$$\begin{aligned}B'&=\sin\phi\,[m_1]-\cos\phi\,[m_2],\\C'&=\sin\phi\,[m_3]-\cos\phi\,[m_4],\\L&=\sin\phi\,[m_3l]-\cos\phi\,[m_4l],\\K&=\sin^2\phi\,[m_3]+\cos^2\phi\,[m_5]-2\sin\phi\cos\phi\,[m_4].\end{aligned}$$

We do not then need to form the usual normal equations, which would be

$$\begin{aligned}[pAA]z+[pAC]y+[pA]z+[pAl]&=0,\\{}[pCC]y+[pC]z+[pCl]&=0,\\{}[p]z+[pl]&=0,\\{}[pll],&\end{aligned}\qquad(a)$$

for we can write at once the *reduced* normal equations

$$\begin{aligned}[pCC.1]y+[pC.1]z+[pCC.1]&=0,\\{}[p.1]z+[pl.1]&=0,\\{}[pll.1],&\end{aligned}\qquad(b)$$

by means of the relations

$$[pCC.1]=[m_6]-\frac{B'^2}{K},\ [pC.1]=[m_1]-\frac{B'C'}{K},\ [pCl.1]=[m_1l]-\frac{B'L}{K},$$

$$[p.1]=[m_3]-\frac{C'^2}{K},\ [pl.1]=[m_3l]-\frac{C'L}{K},$$

$$[pll.1]=[m_3ll]-\frac{L^2}{K}.$$

---

* In this investigation, the collimation constant is considered positive when stars at upper transit require a positive correction for clamp West. It should also be noticed that when the instrument is *very* well adjusted, a_0 and c_0 can be put equal to 0, whereby the computation of l is much facilitated.

From the equations (b), now involving only two unknowns, we get the adjusted values y and z in the usual way. If we wish the value of x also, we get it from the equation—

$$x = -\frac{B'}{K}y - \frac{C'}{K}z - \frac{L}{K}, \qquad (c)$$

where all the coefficients in the second member are known. It will be noticed that the quantities B′, C′, L, K are really coefficients of the usual normal equations (a), but by proceeding at once to the equations (b), we point out the method of reduction for the case of *two* different azimuth constants. We have then, in accordance with the principle already explained, to proceed by the following rule:—

Carry out the reduction for the clamp West and clamp East observations separately, until two separate sets of equations of the form (b) are obtained. Add corresponding coefficients in the two sets, and solve the resulting set in the usual way.

The values of y and z having thus been obtained, the two values of x for clamp West and clamp East result from an application of (c) to the clamp West and clamp East observations respectively. It is, of course, obvious that separate values of a_0 may be assumed in the beginning for the clamp West and clamp East observations, and separate values of B′, C′, L, K will also be found. The peculiar advantage of this method arises from the possibility of tabulating the quantities m_1, m_2, m_3, m_4, m_5, m_6, in tables of single entry. As they are functions of δ only, the values given in the tables which I have computed are good for any latitude. In computing the tables Safford's weight formula* was used. This gives

$$p = \frac{1 \cdot 3}{1 + 0 \cdot 3 \sec^2 \delta},$$

which is often intermediate between the values given by other well-known formulas.† After all, we need only an approximate value of the weight; and, if necessary, tables to agree with any other weight formula could easily be computed from mine by simply multiplying each number by the ratio of the two weights at that particular declination.

It is evident that after an adjustment has been made upon the hypothesis of two azimuths, it is quite easy to obtain the values that would have resulted from the hypothesis of an unchanged azimuth; and such a double solution applied to a number of cases would throw much light upon the question of the desirability of the assumption of two azimuths.

[The tables referred to have been communicated by the author in manuscript. They are preserved in the archives of the Society.]

* *Transactions of the Wisconsin Academy of Science*, vol. vii., 1883–87, p. 199.

† Young, *Washington Observations*, 1878, Appendix ii., p. 29.

Observation of Comet b 1891 (Wolf), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer-Royal.)

The observation was made with the East or Sheepshanks Equatoreal, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55.

Greenwich Mean Solar Time.	Observer.	☄–✱ R.A.	Corr. for Parallax.	Corr. for Refraction.	☄–✱ N.P.D.	Corr. for Parallax.	Corr. for Ref.	No. of Comps.	Apparent R.A.	Tabular R.A.	Apparent N.P.D.	Tabular N.P.D.
d h m s		s	s	s	′ ″	″	″		h m s	h m s	° ′ ″	° ′
Dec. 2 10 10 41	A.C.	−29·90	−·15	+·05	+15 6·1	−8·5	+2·7	5	4 23 36·3	4 23 37	103 32 9·7	103 32·0

Assumed Mean Place of Comparison Star.

Name and Authority.	R.A. 1891·0.	N.P.D. 1891·0.
	h m s	° ′ ″
Greenwich 10-Year Catalogue 1880, No. 718	4 24 3·15	103 17 21·1

In computing the parallax log Δ has been assumed 9·9703, this being interpolated from Berberich's Ephemeris, as is also the Tabular Place. Here and in the observations communicated in the *Monthly Notices* for November, a second term has been applied in the N.P.D. Corr. for Refraction, depending on the difference between apparent and true orientation of the wires; this point was discussed by Col. Tupman in vol. xlviii., p. 96, of the *Monthly Notices.*

The initials "A.C." are those of Mr. Crommelin.

Observations of Comet Encke, made at the Radcliffe Observatory, Oxford.

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

The following observations were made by Mr. Robinson with the Barclay Equatoreal, using the Ring Micrometer, and a power of 100.

Date.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star. (Corrected for Refraction only). R.A.	Comet *minus* Star. N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Parallax in R.A. p	Log. $(p \times \Delta)$	Apparent N.P.D. of Comet.	Parallax in N.P.D. q	Log. $(q \times \Delta)$	Reference to Comp. Star.
1891.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Aug. 12	14 10 7	23 30 0	R.	+1 0·48	+3 10·69	9	4 37 46·92	−0·31	9·6254	57 23 31·9	−3·8	0·7116	(*a*)
Sept. 10	14 21 4	1 35 19	R.	+0 16·98	+7 8·84	9	7 49 59·08	−0·46	9·6382	56 57 2·0	−6·3	0·7765	(*b*)
	14 46 40	2 0 59	R.	−0 27·64	−5 39·44	6	7 50 8·67	−0·46	9·6378	56 57 30·5	−5·9	0·7519	(*c*)
30	16 40 8	5 13 37	R.	−0 45·67	+2 44·00	3	10 41 13·30	−0·39	9·5753	73 58 13·9	−6·6	0·8077	(*d*)
	16 56 24	5 29 55	R.	−0 23·57	+1 53·03	14	10 41 18·72	−0·38	9·5698	73 59 5·9	−6·5	0·8006	(*e*)
Oct. 4	16 27 27	5 16 40	R.	−1 32·60	−1 51·15	2	11 11 23·19	−0·37	9·5707	78 46 29·3	−6·6	0·8291	(*f*)
	16 27 27	5 16 40	R.	−1 48·12	−2 1·37	2	11 11 22·81	−0·37	9·5707	78 46 26·9	−6·6	0·8291	(*g*)
11	17 27 22	6 44 21	R.	−1 15·27	+9 26·93	1	12 2 51·19	−0·32	9·5556	87 38 53·9	−6·0	0·8362	(*h*)

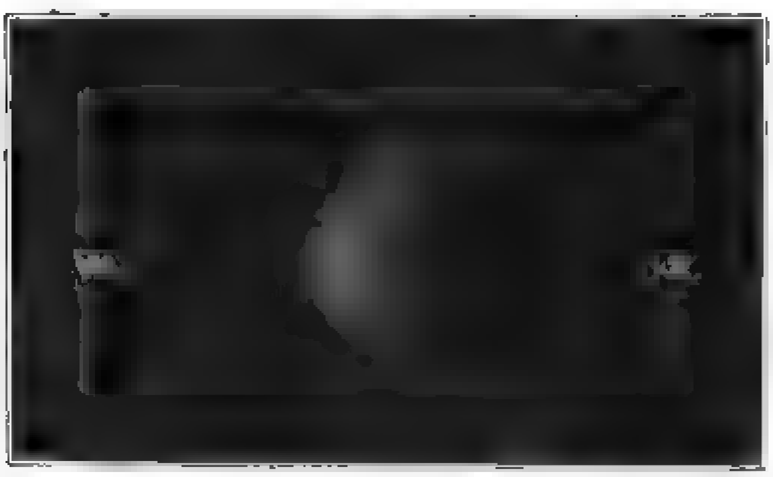
Assumed Places of Comparison Stars.

Comp. Star.	Mean R.A. 1891·0.	Reduction to App. R.A.	Mean N.P.D. 1891·0.	Reduction to App. N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	4 36 45·76	+0·68	57 20 23·3	−2·1	Mean of W.B. (2) IV. 750 and Grant 1138.
(*b*)	7 49 41·41	+0·69	56 49 52·9	+0·3	Radcliffe Transit-circle observation, 1891, Nov. 22.
(*c*)	7 50 35·62	+0·69	57 3 9·6	+0·3	Leiden A.G., Zone 259, No. 118.
(*d*)	10 41 58·57	+0·40	73 55 28·5	+1·5	Radcliffe Transit-circle observation, 1891, Nov. 22.
(*e*)	10 41 41·89	+0·40	73 57 11·4	+1·5	Radcliffe Transit-circle observation, 1891, Nov. 22.
(*f*)	11 12 55·83	+0·34	78 48 18·8	+1·6	Mean of Brussels 4659, and Grant 2914.
(*g*)	11 13 10·92	+0·34	78 48 26·7	+1·6	Mean of Brussels 4661, and Grant 2916.
(*h*)	12 4 6·17	+0·29	87 29 24·8	+2·2	Greenwich (1880), 1892.

Observer's Remarks.

1891, August 12.—The Comet's light is of the feeblest, requiring averted vision to render it visible. No nucleus seen. Centre of patch observed. Sky brilliantly clear.

September 10.—The Coma is fan-shaped, thus:—



The nucleus, which is just within the obtuse angle on the west side, is mag. 13·5.

September 30.—The nucleus is now fairly bright (say 11 mag.). The Coma is very similar in form to that of September 10, but strong twilight obliterated the fainter parts of the Comet.

October 4.—Comet and stars faint; altitude small; sky hazy. Observations made with considerable difficulty.

October 11.—Comet just visible in very strong twilight when stars below the 7th magnitude had disappeared from the field of view.

In the computation of the parallaxes the value 8″·85 has been adopted for the Sun's mean horizontal parallax, and the geocentric distances, Δ, have been taken from an ephemeris by Dr. O. Backlund, given in the *Astronomische Nachrichten*, No. 3048.

Radcliffe Observatory, Oxford:
1891 *December* 3.

Observations of Comet Barnard 1891, *made at Sydney Observatory.*

(*Communicated by H. C. Russell, B.A., F.R.S., Government Astronomer.*)

This comet was found on October 9. It is a faint, round body with slight central condensation. The observations were made with the Filar Micrometer on the 11½-inch equatoreal, Mr. R. P. Sellars observing. Cloudy weather and then moonlight have prevented us from obtaining any observations since the 11th.

1891.	Syd. M. T.	Δ R.A.	Δ N.P.D.	cp.	R.A. app.	log p. Δ	N.P.D. app.	log p. Δ	Red. ad l. app.		*
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Oct. 9	13 52 24	+0 58·31	− 4 34·52	22	8 9 23·26	9·773n	126 34 52·53	0·462	+0·50	−16·71	1
9	16 2 51	−0 0·61	+ 5 17·99	15	8 10 0·09	9·626n	126 42 18·32	9·877	+0·51	−16·61	2
11	13 58 58	+5 49·39	− 1 12·44	12	8 23 17·40	9·789n	129 14 56·96	0·428	+0·45	−16·60	3
11	15 45 12	+2 17·42	−10 1·17	13	8 23 48·70	9·683n	129 20 49·14	9·887	+0·41	−16·36	4

Mean Places of Comparison Stars for 1891·0.

*	R.A. 1891·0.	N.P.D. 1891·0.	Authority.
	h m s	° ′ ″	
1	8 8 24·45	126 39 43·76	St. 4204, Arg. Gen. Cat. 10931 and 10964 (1ᵐ in error).
2	8 10 0·19	126 37 16·94	Arg. Gen. Cat. 10980.
3	8 17 27·56	129 16 26·00	St. 4297, Arg. Gen. Cat. 11199.
4	8 21 30·87	129 31 6·67	Arg. Gen. Cat. 11311.

Sydney Observatory: 1891 *October* 19.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. LII. January 8, 1892. No. 3

E. J. Stone, M.A., F.R.S., Vice-President, in the Chair.

Edward Herbert Lees, Orbost, Victoria, Australia;
J. de Mendizábal Tamborrel, 13 Calle de Jesús, Mexico;
J. S. Slater, Professor of Civil Engineering, Civil Engineering College, Seebpore, Calcutta;
Arthur Thornton, M.A., Christ's College, Cambridge, Giggleswick School, Yorkshire.
W. Livingstone Watson, Ayton, Abernethy, Perthshire,

were balloted for and duly elected Fellows of the Society.

The following candidate was proposed for election as a Fellow of the Society, the name of the proposer, from personal knowledge, being appended:—

Arthur Gibbons, Lecturer in Science, Head Master of the Science, Art, and Technical School, Brierley Hill, Dudley (proposed by J. C. Roger).

Fifty-six presents were announced as having been received since the last meeting, including, amongst others:—

Preparation and discussion of the Draper Catalogue, by E. C. Pickering (*Harvard Observatory Annals*, vol. xxvi. part 1), presented by the Observatory; the collected Mathematical papers of Arthur Cayley, vol. iv., presented by the author.

Note on some Values of the Sun's Mean Horizontal Parallax which have been deduced from the Transit of Venus Observations made in 1882. By E. J. Stone, M.A., F.R.S., *Radcliffe Observer.*

The recent publication by Professors Harkness and Auwers of the results obtained by them from the Photographic and Heliometer Observations of the Transit of *Venus*, 1882, has suggested to me the desirability of recalling attention to the results obtained, 1887, from a discussion of the contact observations of the Transit of *Venus* which were made in co-operation with the expeditions sent out by the British Government.

If $d\alpha^s$ and $d\Delta''$ denote the relative corrections, in right ascension and north polar distance respectively, which are required by Le Verrier's Tables of *Venus* and the Sun for the time of the transit, the values of the mean horizontal equatorial parallax π, which I found from the "Internal Contacts," were expressed under the forms

Ingress Observations:

$$\pi = 8''\cdot823 \pm 0\cdot033 + 0\cdot065 \,.\, d\alpha^s - 0\cdot0027 \,.\, d\Delta''.$$

Egress Observations:

$$\pi = 8''\cdot855 \pm 0\cdot036 - 0\cdot068 \,.\, d\alpha^s - 0\cdot0099 \,.\, d\Delta'',$$

or, combining the results,

$$\pi = 8''\cdot839 \pm 0\cdot024 - 0\cdot0015 \,.\, d\alpha^s - 0\cdot0063 \,.\, d\Delta''.$$

The resulting values of π in these equations are slightly affected by any existing errors $d\alpha^s$ and $d\Delta''$.

The Photographic and Heliometer Observations should afford special facilities for the determination of such relative corrections as $d\alpha^s$ and $d\Delta''$, and the results obtained by Professors Harkness and Auwers for these quantities are in close agreement.

If we adopt the values found by Professor Auwers, viz.:

$$d\alpha^s = \frac{9''\cdot13}{15},\ d\Delta'' = -1''\cdot99,$$

the value of π given by the Internal Contacts becomes

$$\pi = 8''\cdot850 \pm 0''\cdot024.$$

The results obtained by Professors Harkness and Auwers are respectively:

$$\pi = 8'\cdot842 \pm 0\cdot011$$

$$\pi = 8''\cdot883 \pm 0\cdot022,$$

which agree in a very satisfactory manner with that which I have found from the Internal Contacts, viz.:

$$\pi = 8''\cdot850 \pm 0\cdot022.$$

The results given by the other contacts observed in 1882 agree within the probable errors of their determinations with those obtained from the Internal Contacts.

On the Relation between Diameter of Image, Duration of Exposure, and Brightness of Objects in Photographs of Stars taken at the Royal Observatory, Greenwich. By W. H. M. Christie, M.A., F.R.S., Astronomer Royal.

Since the 13-inch photographic equatoreal was mounted and brought into working order, a number of experimental photographs have been taken at Greenwich with a view to determining the increase of diameter of star disc with exposure, and the relation between the brightness of a star and the exposure required to photograph it. Thanks to the fine definition and excellent clock-work of Sir Howard Grubb's instrument, the star images on these photographs are as a rule remarkably sharp, and very small measurable discs have been obtained in the case of faint stars.

Photographs of selected regions, for which Professor Pritchard has determined with the wedge photometer the magnitudes of certain stars of 9th and 11th magnitude, have been taken with a graduated series of exposures, and the diameters of the star discs on certain of these photographs have been measured under a microscope with a filar micrometer. The microscope has a magnifying power of about 15, referred to a distance of 10 inches. The star discs measured were scattered over the field up to a distance of 60′ from the centre, the plates being placed about 1^{mm} within the focus for the centre, *i.e.* focussed on a point about 52′ from the centre, so as to equalise the definition over the field.

I.—*The Relation between Diameter of Image and Duration of Exposure.*

Two distinct formulæ have been proposed to express this relation, both of which are, from the nature of the case, empirical:—

1. The diameter varies as a power of the exposure, *i.e.*,

$$\frac{d}{d_0} = \left(\frac{t}{t_0}\right)^p \quad \text{or} \quad \log d - \log d_0 = p\,(\log t - \log t_0)$$

where d, d_0 are the diameters of the images of the same star corresponding to exposures of t^s and t^s_0 respectively under similar

conditions, and p should be a constant; p has been found by Professor Pritchard, M. Charlier, and others to be one-quarter, but Bond found it to be one-half, and Mr. Turner found that it varied from less than one-third for small diameters to more than one-third for large diameters, tending towards the square root for the former and towards the fourth root for the latter.

2. The diameter increases as the logarithm of the exposure, *i.e.*,

$$d - d_0 = m\,(\log t - \log t_0)$$

where m should be a constant.

It will be shown that neither of these formulæ satisfactorily represents the measures of diameters on the Greenwich photographs, the discussion of which leads to the conclusion that the square root of the diameter increases as the logarithm of the exposure, *i.e.*,

$$\sqrt{d} - \sqrt{d_0} = n\,(\log t - \log t_0),$$

n being very nearly unity when d is expressed in seconds of arc.

The following tables give the results of measures of diameters of star images with various exposures, on six photographs, the exposure being made in the order stated under each photograph. The total number of measures here discussed is about 2220, 830 images of 153 stars having been measured, each at least twice, and usually by two or more measurers. The initials of the Measurers, A. E., A. R., E. R., and W. C., are those of Miss Everett, Miss Russell, Miss Rix, and Mr. Christie. Care was taken to make the measures on the same system throughout, the diameter measured being intermediate between that of the extreme penumbra and of the nucleus, so that it should represent fairly the total photographic action in the case of small faint images as well as of the denser images. In a few cases, where a line of the *réseau* or a defect on the film interfered with the image, it has been necessary, in taking means for groups, to supply a value of diameter by comparison with other measures, without, however, introducing any appreciable uncertainty in the result.

In the several columns of the tables are given:—1. Duration of exposure in seconds; 2, its logarithm; 3, diameter in seconds of arc; 4, its square root; 5, its logarithm; 6, 7, and 8, the resulting values for m, n, and p in the three formulæ given above, formed by dividing the respective differences of consecutive values of d, $\sqrt{d}$ and $\log d$ by the differences of $\log t$. The progression in the values of m and p is evident, and it is clear that the value 0·25 for p will not represent the smaller diameters. The magnitudes given for stars of 9 and 11 magnitudes (marked photom.) are taken from the lists recently issued from the Oxford University Observatory for selected fields, which have proved of the greatest service in the inquiry. The numeration of the stars (1 to 12, 9 mag., 13 to 24, 11 mag.) has also been taken

from these lists. Argelander's magnitudes from the Bonn Durchmusterung are given for the brighter stars.

Photo. 128. λ *Serpentis.* 1891 July 17.

Exposures: 12^s, 15^s, 20^s, 30^s, 40^s, 250^s, $187\frac{1}{2}^s$, 125^s, 94^s, 75^s.

Photographer: Mr. Criswick.

Measurers: A. E., E. R., W. C. Each star was measured by 3 observers, 5 measures in all being made in most cases.

I. λ *Serpentis*; 4·5 mag. (Arg.); 4·7 (Uran. Oxon.).

t	log t	d	$\sqrt{d}$	log d	m	n	p
s		"	"				
250	2·398	19·70	4·44	1·295	12·1	1·44	·28
187½	2·273	18·19	4·26	1·260	11·6	1·36	·30
125	2·097	16·15	4·02	1·208	5·4	0·73	·14
94	1·973	15·48	3·93	1·190	7·3	0·92	·21
75	1·875	14·76	3·84	1·169	3·6	0·48	·11
40	1·602	13·78	3·71	1·139	7·9	1·04	·26
30	1·477	12·79	3·58	1·107	7·5	1·08	·27
20	1·301	11·47	3·39	1·060	4·2	0·64	·17
15	1·176	10·94	3·31	1·039	4·4	0·72	·18
12	1·079	10·51	3·24	1·022			

II. 5 stars. 8·8 to 9·2 mag.

Mean mag. 9·06 photom. (9·04 Arg.)

		"	"				
250	2·398	6·41	2·53	0·807	5·0	1·04	·36
187½	2·273	5·78	2·40	0·762	2·6	0·51	·20
125	2·097	5·33	2·31	0·727	5·6	1·29	·48
94	1·973	4·63	2·15	0·666	5·4	1·33	·54
75	1·875	4·10	2·02	0·613	3·2	0·84	·39
40	1·602	3·22	1·79	0·508	2·9	0·80	·42
30	1·477	2·86	1·69	0·456	2·7	0·85	·45
20	1·301	2·38	1·54	0·377	2·2	0·72	·41
15	1·176	2·11	1·45	0·324	2·7	0·93	·61
12	1·079	1·85	1·36	0·267			

III. 9 stars. 10·7 to 11·2 mag.

Mean mag. 10·96 photom.

s		"	"				
250	2·398	2·96	1·72	0·471	2·9	0·88	·45
187½	2·273	2·60	1·61	0·415	3·4	1·14	·65
125	2·097	2·00	1·41	0·301	1·1	0·32	·24
94	1·973	1·87	1·37	0·272			

Photo. 174. ω^2 *Cygni.* 1891 October 7.

Exposures: 5^s, 10^s, 20^s, 40_1^s, 80_1^s, 640^s, 320^s, 160^s, 80_2^s, 40_2^s.
Photographer: Miss Rix.

Measurers: A. E., W. C., E. R., 2 measures by each; 40_1^s and 40_2^s, 80_1^s and 80_2^s, were measured separately, and as there appeared to be no systematic difference between 40_1^s and 40_2^s, and between 80_1^s and 80_2^s, the means of each pair were taken.

a. ω^2 *Cygni.* 4·9 mag. (Arg.), 5·0 (Uran. Oxon.).

t	log *t*	*d*	$\sqrt{d}$	log *d*	*m*	*n*	*p*
s 640	2·806	31·07″	5·58″	1·493	14·2	1·33	·22
320	2·505	26·80	5·18	1·428	16·2	1·67	·29
160	2·204	21·94	4·68	1·341	11·4	1·23	·24
80	1·903	18·50	4·31	1·268	6·8	0·83	·17
40	1·602	16·46	4·06	1·217	8·6	1·10	·25
20	1·301	13·26	3·73	1·142	5·1	0·74	·17
10	1·000	12·32	3·51	1·091	9·3	1·41	·37
5	0·699	9·53	3·09	0·979			

b. B.D. + 48°, 3154; 5·9 mag. (Arg.)

t	log *t*	*d*	$\sqrt{d}$	log *d*	*m*	*n*	*p*
s 640	2·806	16·56″	4·07″	1·219	8·5	1·11	·24
320	2·505	14·00	3·74	1·146	7·2	1·01	·24
160	2·204	11·84	3·44	1·073	5·3	0·80	·27
80	1·903	10·24	3·20	1·010	6·2	1·03	·29
40	1·602	8·38	2·89	0·923	7·9	1·47	·49
20	1·301	5·99	2·45	0·777	7·8	1·80	·73
10	1·000	3·64	1·91	0·561	5·9	1·77	·94
	0·699	1·90	1·38	0·279			

c. B.D. + 48°, 3148; 7·5 mag. (Arg.)

t	log *t*	*d*	$\sqrt{d}$	log *d*	*m*	*n*	*p*
s 540	2·806	18·33″	4·28″	1·263	9·2	1·11	·24
320	2·505	15·56	3·95	1·192	8·6	1·16	·26
160	2·204	12·98	3·60	1·113	6·8	0·97	·25
80	1·903	10·94	3·31	1·039	4·5	0·74	·19
40	1·602	9·58	3·09	0·981	7·1	1·21	·37
20	1·301	7·43	2·73	0·871	4·5	0·90	·29
10	1·000	6·07	2·46	0·783	8·4	1·91	·77
5	0·699	3·55	1·89	0·550			

d. B.D. + 48°, 3128; 6·0 mag. (Arg.); 5·64 mag. (Harv. Photom.).

t	log *t*	*d*	$\sqrt{d}$	log *d*	*m*	*n*	*p*
s		″	″				
640	2·806	19·41	4·41	1·288	8·4	1·00	·23
320	2·505	16·87	4·11	1·227	10·0	1·31	·28
160	2·204	13·87	3·72	1·142	8·4	1·16	·29
80	1·903	11·33	3·37	1·054	4·3	0·67	·18
40	1·602	10·03	3·17	1·001	5·8	0·96	·27
20	1·301	8·30	2·88	0·919	4·0	0·73	·23
10	1·000	7·10	2·66	0·851	7·1	1·43	·51
5	0·699	4·99	2·23	0·698			

e. B.D. + 49°, 3310; 6·7 mag. (Arg.)

t	log *t*	*d*	$\sqrt{d}$	log *d*	*m*	*n*	*p*
s		″	″				
640	2·806	13·78	3·71	1·139	5·4	0·73	·18
320	2·505	12·16	3·49	1·085	7·1	1·07	·28
160	2·204	10·03	3·17	1·001	6·8	1·13	·33
80	1·903	7·98	2·83	0·902	2·1	0·40	·12
40	1·602	7·35	2·71	0·866	5·6	1·11	·37
20	1·301	5·68	2·38	0·754	2·8	0·60	·23
10	1·000	4·83	2·20	0·684	3·9	0·93	·40
5	0·699	3·67	1·92	0·564			

g. B.D. + 49°, 3298; 6·9 mag. (Arg.)

t	log *t*	*d*	$\sqrt{d}$	log *d*	*m*	*n*	*p*
s		″	″				
640	2·806	12·71	3·57	1·104	4·0	0·60	0·33
320	2·505	11·51	3·39	1·004	7·9	1·23	0·14
160	2·204	9·14	3·02	0·961	5·6	0·97	0·30
80	1·903	7·45	2·73	0·872	3·8	0·73	0·24
40	1·602	6·30	2·51	0·799	6·0	1·29	0·48
20	1·301	4·51	2·12	0·654	2·6	0·64	0·28
10	1·000	3·73	1·93	0·571	5·4	1·60	0·82
5	0·699	2·10	1·45	0·323			

2. B.D. + 48°, 3145; 9·0 mag. (Arg.); 9·02 mag. (photom.)

t	log *t*	*d*	$\sqrt{d}$	log *d*	*m*	*n*	*p*
s		″	″				
640	2·806	9·51	3·08	0·978	7·2	1·23	0·38
320	2·505	7·33	2·71	0·865	4·9	0·98	0·33
160	2·204	5·86	2·42	0·768	8·1	1·87	0·77
80	1·903	3·45	1·86	0·538	2·6	0·74	0·37
40	1·602	2·68	1·64	0·428			

Photo. 178. 36 *Pegasi.* 1891 October 9.

Exposures: 5^s, 10^s, 20^s, 40_1^s, 80_1^s, 640^s, 320^s, 160^s, 80_2^s, 40_2^s, 10_2^s.

Photographer: Mr. Criswick.

Measurers: A. E, A. R.

40_1^s and 40_2^s, 80_1^s and 80_2^s, were measured separately and the means of each pair taken.

I. 5 stars. Nos. 1–5. 8·6 to 9·0 mag. photom,

Mean mag. 8·90 photom. (9·08 Arg.)

t	log *t*	*d*	√*d*	log *d*	*m*	*n*	*p*
s		"	"				
640	2·806	8·02	2·83	0·905	6·3	1·16	·39
320	2·505	6·14	2·48	0·789	3·6	0·77	·28
160	2·204	5·06	2·25	0·705	6·0	1·50	·64
80	1·903	3·25	1·80	0·513	3·7	1·13	·62
40	1·602	2·12	1·46	0·328	2·4	0·93	·60
20	1·301	1·40	1·18	0·148			

II. 4 stars. Nos. 8, 9, 11, 12. 9·2 to 9·4 mag. photom.

Mean mag. 9·28 photom. (9·25 Arg.)

t	log *t*	*d*	√*d*	log *d*	*m*	*n*	*p*
s		"	"				
160	2·204	3·43	1·85	0·536	4·1	1·20	·64
80	1·903	2·21	1·49	0·345	2·8	1·06	·68
40	1·602	1·38	1·17	0·141			

III. 7 stars. Nos. 13–19. 10·8 to 11·0 mag. photom.

Mean mag. 10·87 photom.

t	log *t*	*d*	√*d*	log *d*	*m*	*n*	*p*
s		"	"				
640	2·806	3·74	1·93	0·574	4·4	1·26	·64
320	2·505	2·41	1·55	0·383	3·8	1·43	·94
160	2·204	1·26	1·12	0·101			

IV. 5 stars. Nos. 20–24. 11·0 to 11·3 mag. photom.

Mean mag. 11·16 photom.

t	log *t*	*d*	√*d*	log *d*	*m*	*n*	*p*
s		"	"				
640	2·806	2·47	1·57	0·394	4·0	1·46	·95
320	2·505	1·28	1·13	0·109			

Photo. 180. 36 *Pegasi.* 1891 October 12.

Exposures: 63_1^s, 398^s, 251^s, 159^s, 100^s, 63_2^s, 10^s, 16^s, 25^s, 40^s, 63_3^s.

Photographer: Miss Everett.

Measurers: E. R., A. E.

63_2^s and 63_3^s were measured for Group I. and the means taken.

I. 3 stars. 36 *Pegasi*, B.D. + 8°·5880, B.D. + 8°·5870.

Mags. 5·8, 7·7, 7·8 Arg.

t	log t	d	$\sqrt{d}$	log d	m	n	p
s		″	″				
398	2·600	12·90	3·59	1·111	5·7	0·80	·20
251	2·400	11·76	3·43	1·071	7·2	1·10	·29
159	2·201	10·32	3·21	1·014	5·7	0·90	·26
100	2·000	9·18	3·03	0·963	5·7	0·95	·29
63	1·799	8·04	2·84	0·905	4·8	0·90	·28
40	1·602	7·08	2·66	0·850	3·9	0·75	·26
25	1·398	6·30	2·51	0·799	5·1	1·05	·38
16	1·204	5·28	2·30	0·723	7·2	1·70	·70
10	1·000	3·84	1·96	0·584			

II. 3 stars. Nos. 1, 5, 6. 8·6 to 9·1 mag.

Mean mag. 8·90 photom. (9·03 Arg.)

s		″	″				
398	2·600	6·54	2·56	0·816	4·5	0·95	·33
251	2·400	5·64	2·37	0·751	5·4	1·15	·46
159	2·201	4·56	2·14	0·659	3·6	0·90	·38
100	2·000	3·84	1·96	0·584	2·4	0·60	·29
63_2	1·799	3·36	1·84	0·526	3·0	0·90	·43
40	1·602	2·76	1 66	0·441	3·3	1·05	·60
25	1·398	2·10	1·45	0·322	2·7	1·00	·65
16	1·204	1·56	1·25	0·193			

III. 6 stars. Nos. 1–6. 8·6 to 9·1 mag.

Mean mag. 8·93 photom. (9·12 Arg.)

s		″	″				
63_2	1·799	3·48	1·87	0·542	3·6	1·05	·51
40	1·602	2·76	1·66	0·441	2·1	0·65	·36
25	1·398	2·34	1·53	0·369	3·6	1·30	·79
16	1·204	1·62	1·27	0·210			

IV. 6 stars. Nos. 7–12. 9·1 to 9·4 mag.

Mean mag. 9·25 photom. (9·20 Arg.)

s		″	″				
63_2	1·799	2·46	1·57	0·391	2·1	0·70	·41
40	1·6c2	2·04	1·43	0·310	2·4	0·90	·59
25	1·398	1·56	1·25	0·193			

V. 8 stars. Nos. 13–20. 10·8 to 11·0 mag.

Mean mag. 10·89 photom.

s		″	″				
398	2·600	3·00	1·73	0·477	3·0	0·90	0·49
251	2·400	2·40	1·55	0·380	1·8	0·60	0·35
159	2·201	2·04	1·43	0·310	2·4	0·90	0·59
100	2·000	1·56	1·25	0·193			

VI. 4 stars. Nos. 21–24. 11·1 to 11·3 mag.

Mean mag. 11·20 photom.

t	log *t*	*d*	√*d*	log *d*	*m*	*n*	*p*
398ˢ	2·600	2″·40	1″·55	0·380	4·8	1·75	1·11
251	2·400	1·44	1·20	0·158	1·2	0·50	0·40
159	2·201	1·20	1·10	0·079			

Photo. 181. 36 *Pegasi.* 1891 October 12.

Exposures: 100_1^{s}, 631^{s}, 398^{s}, 100_2^{s}, 16^{s}, 25^{s}, 40^{s}, 40^{s}, 63^{s}, 100_3^{s}.

Photographer: Miss Everett.

Measurers: A. E., A. R.

It was intended also to have exposures of 251^{s} and 159^{s}, but, as there is only one image corresponding, it has been thought better not to use the measures of this image, there being no means of determining which exposure it represents. There seems to be no doubt as to the long exposures of 631^{s} and 398^{s}, the clock times of beginning and ending having been recorded. The exposure 100_2^{s} is checked by the measures for 100_3^{s}. The sky was not quite free from cloud.

I. 3 stars. 36 *Pegasi*, B.D. + 8°·5880, B.D. + 8°·5870. Mags. 5·8, 7·7, 7·8 Arg.

t	log *t*	*d*	√*d*	log *d*	*m*	*n*	*p*
631ˢ	2·800	14″·72	3″·84	1·168	5·9	0·80	0·18
398	2·600	13·54	3·68	1·132	4·7	0·67	0·17
100_2	2·000	10·76	3·28	1·032			
100_3	2·000	10·68	3·27	1·029	10·6	1·75	0·48
63	1·799	8·60	2·93	0·935	6·3	1·10	0·35
40	1·602	7·35	2·71	0·866	6·5	1·25	0·42
25	1·398	6·06	2·46	0·783	6·4	1·35	0·52
16	1·204	4·78	2·19	0·679			

II. 3 stars, Nos. 1, 5, 6. 8·6 to 9·1 mag.

Mean mag. 8·90 photom. (9·03 Arg.)

t	log *t*	*d*	√*d*	log *d*	*m*	*n*	*p*
631ˢ	2·800	7″·36	2″·71	0·867	4·5	0·85	0·29
398	2·600	6·46	2·54	0·810	3·5	0·73	0·28
100_2	2·000	4·32	2·08	0·636			
100_3	2·000	4·46	2·11	0·649	6·7	1·75	0·79
63	1·799	3·06	1·75	0·486	2·1	0·65	0·32
40	1·602	2·64	1·62	0·422	3·2	1·05	0·61
25	1·398	2·00	1·41	0·301	3·1	1·20	0·81
16	1·204	1·38	1·17	0·140			

III. 6 stars, Nos. 1–6. 8·6 to 9·1 mag.

Mean mag. 8·93 photom. (9·12 Arg.)

t	log t	d	$\sqrt{d}$	log d	m	n	p
s		″	″				
100_2	2·000	4·76	2·18	0·678			
100_3	2·000	4·68	2·16	0·670	7·0	1·75	0·77
63	1·799	3·32	1·82	0·521	3·0	0·85	0·43
40	1·602	2·72	1·65	0·435	3·5	1·15	0·65
25	1·398	2·02	1·42	0·305	3·1	1·20	0·79
16	1·204	1·40	1·18	0·146			

IV. 6 stars, Nos. 7–12. 9·1 to 9·4 mag.

Mean mag. 9·25 photom. (9·20 Arg.)

s		″	″				
100_2	2·000	3·83	1·96	0·583			
100_3	2·000	3·56	1·89	0·551	6·3	1·85	0·90
63	1·799	2·44	1·56	0·387	3·6	1·25	0·76
40	1·602	1·72	1·31	0·236	1·4	0·55	0·39
25	1·398	1·44	1·20	0·158			

V. 8 stars, Nos. 13–20. 10·8 to 11·0 mag.

Mean mag. 10·89 photom.

s		″	″				
631	2·800	3·98	1·99	0·601	5·3	1·40	·68
398	2·600	2·92	1·71	0·465	1·8	0·57	·33
100_2	2·000	1·71	1·33	0·232			
100_3	2·000	1·97	1·40	0·295	2·6	1·10	·72
63	1·799	1·32	1·15	0·121			

VI. 4 stars, Nos. 21–24. 11·1 to 11·3 mag.

Mean mag. 11·20 photom.

s		″	″				
631	2·800	3·01	1·73	0·477	3·3	1·00	·53
398	2·600	2·35	1·53	0·371	1·4	0·50	·33
100_2	2·000	1·55	1·24	0·190			
100_3	2·000	1·49	1·22	0·173			

Photo. 185. ω^2 *Cygni.* 1891 October 14.

Exposures: $41^m\ 52^s$, 251^s, 40^s, 25^s, 159^s, 100^s, 16^s.

Photographer: Miss Everett.

Measurers: A. E., A. R. Ten measures of ω^2 *Cygni* by A. E. and A. R. and 2 measures of each of the other stars by A. E. or A. R. (alternately).

I. ω^2 *Cygni.* 4·9 mag. (Arg.) 5·0 (*Uran. Oxon.*).

t	$\log t$	d	$\sqrt{d}$	$\log d$	m	n	p
m s		″	″				
41 52	3·400	45·62	6·75	1·659	18·10	1·50	0·22
251	2·400	27·52	5·25	1·440	14·7	1·47	·25
159	2·201	24·60	4·96	1·391	11·0	1·69	·30
100	2·000	21·38	4·62	1·330	11·0	1·26	·25
40	1·602	17·00	4·12	1·230	8·6	1·08	·23
25	1·398	15·24	3·90	1·183	6·9	0·88	·21
16	1·204	13·90	3·73	1·143			

II. 8 stars. 5·9 to 7·9 mag. Arg.

Mean mag. 7·08 Arg.

t	$\log t$	d	$\sqrt{d}$	$\log d$	m	n	p
m s		″	″				
41 52	3·400	25·49	5·05	1·406	11·1	1·25	·25
251	2·400	14·42	3·80	1·159	8·9	1·12	·29
159	2·201	12·65	3·56	1·102	7·6	1·15	·28
100	2·000	11·12	3·33	1·046	5·2	0·80	·22
40	1·602	9·07	3·01	0·958	5·8	1·00	·30
25	1·398	7·88	2·81	0·897	6·3	1·19	·38
16	1·204	6·66	2·58	0·824			

III. 6 stars. 6·8 to 8·0 mag. Arg.

Mean mag. 7·35 Arg.

t	$\log t$	d	$\sqrt{d}$	$\log d$	m	n	p
m s		″	″				
41 52	3·400	17·08	4·13	1·232	7·9	1·11	·27
251	2·400	9·14	3·02	0·961	6·0	1·01	·31
159	2·201	7·94	2·82	0·900	5·7	1·05	·33
100	2·000	6·80	2·61	0·833	4·0	0·83	·29
40	1·602	5·20	2·28	0·716	5·5	1·28	·52
25	1·398	4·08	2·02	0·611	3·8	0·98	·45
16	1·204	3·34	1·83	0·524			

IV. 3 stars. 8·64 to 9·02 mag. photom.

Mean mag. 8·86 photom. (9·07 Arg.)

t	$\log t$	d	$\sqrt{d}$	$\log d$	m	n	p
m s		″	″				
41 52	3·400	16·18	4·02	1·209	7·7	1·11	·28
251	2·400	8·44	2·91	0·926	4·8	0·91	·26
159	2·201	7·48	2·73	0·874	6·6	1·25	·42
100	2·000	6·16	2·48	0·790	4·6	1·00	·39
40	1·602	4·32	2·08	0·636	2·4	0·59	·26
25	1·398	3·84	1·96	0·584	4·4	1·19	·57
16	1·204	2·98	1·73	0·474			

V. 9 stars. 8·99 to 9·39 mag. photom.

Mean mag. 9·17 photom. (9·32 Arg.)

t	log t	d	$\sqrt{d}$	log d	m	n	p
m s							
41 52	3·400	11·94″	3·46″	1·077	6·4	1·10	·33
251	2·400	5·56	2·36	0·745	6·2	1·40	·54
159	2·201	4·33	2·08	0·637	4·6	1·15	·52
100	2·000	3·41	1·85	0·532	2·4	0·71	·35
40	1·602	2·47	1·57	0·393	3·1	1·03	·63
25	1·398	1·84	1·36	0·265	3·0	1·24	·85
16	1·204	1·26	1·12	0·100			

VI. 12 stars. 10·7 to 11·2 mag. photom.

Mean mag. 10·93 photom.

t	log t	d	$\sqrt{d}$	log d	m	n	p
m s							
41 52	3·400	6·24″	2·50″	0·795	3·6	0·89	·38
251	2·400	2·58	1·61	0·412	3·0	1·01	·57
159	2·201	1·99	1·41	0·299	1·8	·65	·43
100	2·000	1·63	1·28	0·212			

The values of p and n have been grouped, taking log. diameter as argument, and the means of the groups, with the number of values in each group, are exhibited in the following table, which shows clearly the progression in the values for p, while n is sensibly constant. The values corresponding to the 5^s exposure in Photo. 174 have not been used in forming these means, as there might be a sensible error in estimating the duration of such a short exposure. For simplicity of computation the values of p and n have been treated as of equal weight in forming the means.

Means of Groups.

Log. Diam. Limits.	Log. Diam. Mean.	No. in Group.	Diam.	$\sqrt{\text{Diam.}}$	p	n	Discordance from Mean.
0·12–0·30	0·24	19	1·74″	1·32″	·657	0·996	–·039
0·31–0·41	0·36	12	2·29	1·51	·530	0·910	–·125
0·42–0·53	0·46	16	2·88	1·70	·526	1·039	+·004
0·56–0·66	0·61	15	4·07	2·02	·508	1·185	+·150
0·67–0·78	0·72	12	5·25	2·29	·403	1·060	+·025
0·78–0·88	0·83	14	6·76	2·60	·351	1·047	+·012
0·88–0·98	0·92	15	8·32	2·88	·301	1·017	–·018
0·98–1·08	1·03	16	10·72	3·27	·242	0·924	–·111
1·08–1·18	1·13	15	13·49	3·67	·220	0·922	–·113
1·18–1·55	1·30	17	19·95	4·47	·240	1·246	+·211
	Total ...	151			Mean ...	1·0346	± ·085

The discordances from the mean in the separate values of n (given in the last column) appear to be accidental, and we may conclude that the formula—

$$\sqrt{d} - \sqrt{d_0} = 1{\cdot}03\ (\log t - \log t_0),$$

or

$$\sqrt{\text{diam.}} = 1{\cdot}03 \times \log \text{exposure} + \text{const.}$$

(the diameter being expressed in seconds of arc) represents the measures satisfactorily, through the range $1''{\cdot}3$ to $35''{\cdot}5$ in the diameters, corresponding to a range of 8 magnitudes, or to a ratio of 1 to 1600 in the limiting light-intensities.

The following are the probable errors of a determination of n in the tables, inferred from the discordances from the mean in the several groups:

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	Mean
·259	·196	·191	·337	·264	·143	·156	·177	·158	·186	·207

Each of these values represents the probable error of a determination of the quantity $\frac{\sqrt{d}-\sqrt{d'}}{\log t - \log t'}$. The mean value of $\log t - \log t' = 0{\cdot}226$, whence the probable error of a determination of $\sqrt{d}-\sqrt{d'}$ is 0·047, corresponding to 0·117 magnitude, since 0·4 in $\log t - \log t'$ or in $\sqrt{d}-\sqrt{d'}$ represents 1 magnitude. The probable error of a result for $\sqrt{d}$ in the above tables is therefore $\frac{0{\cdot}047}{\sqrt{2}} = 0{\cdot}033$, corresponding to 0·083 magnitude. Each of these results for $\sqrt{d}$ is the mean of about eleven measures, either of one star or of a small group, all taken with the same exposure, there being 2220 measures for 197 values of $\sqrt{d}$. In this probable error is included the systematic error depending on the state of the sky and other causes incidental to the particular exposure, this systematic error being probably an important element in the probable error inferred from the discordances in the values of n.

The probable error for a determination of n in the tables appears to be approximately the same for each of the ten groups, though it tends to become slightly smaller for the groups with larger diameter and longer exposure.

As the value of n for each group is the mean of about fifteen separate values (on the average), its probable error (considering all the groups as of approximately the same weight) would be 0·053, and the mean error 0·063; whereas the mean discordance from the formula is 0·085, a quantity which so slightly exceeds the computed mean error, that the formula may safely be taken as representing the observations within the limits of accidental error.

The accompanying curves exhibit the results graphically.

Fig. 1 shows the value of p as ordinate, with log. diameter as abscissa, the curve being drawn freely by hand among the dots.

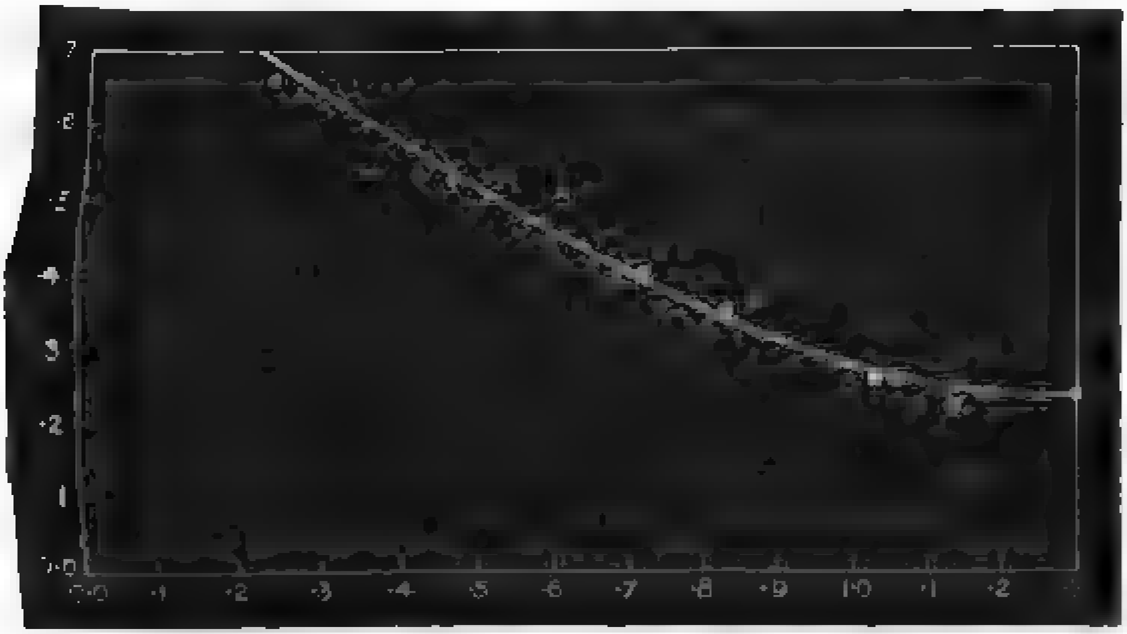
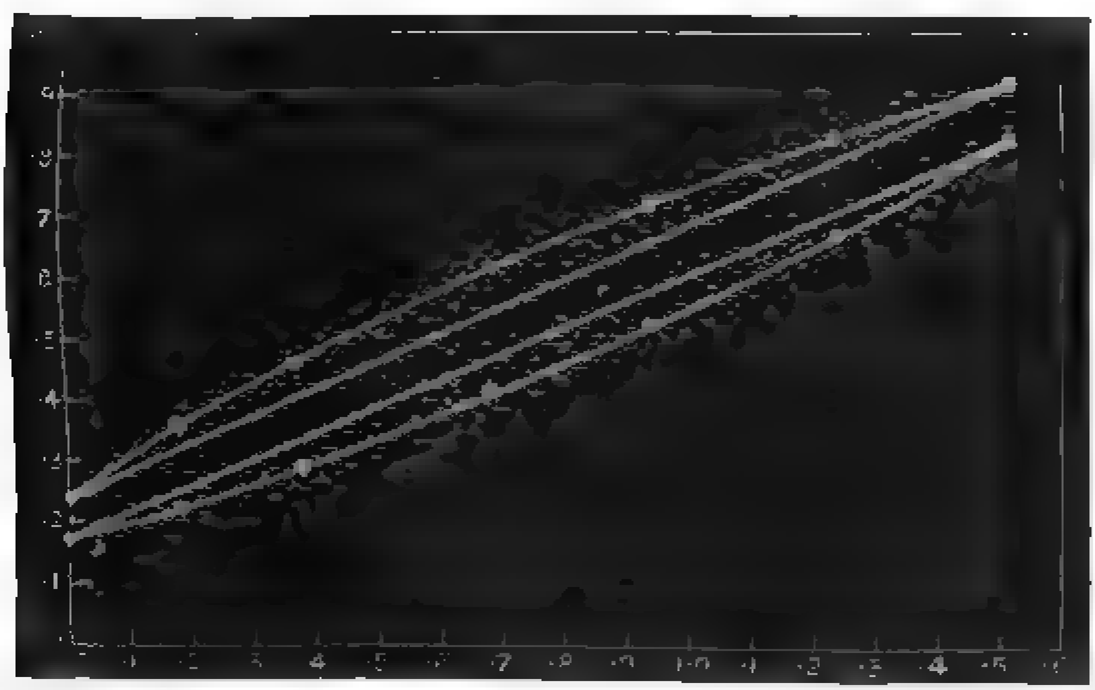


Fig. 2.—The upper curve represents the log. diameter (as ordinate), and the lower the diameter (as ordinate), with the log. duration of exposure (diminished by a constant) as abscissa, the abscissa being deduced from the log. diameter by summation, taking the value of p from the curve in fig. 1. The straight lines represent the formulæ

$$\log d - \log d_0 = p\,(\log t - \log t_0),$$

and

$$d - d_0 = m\,(\log t - \log t_0).$$



where m and p are constants deduced from the extreme values. The latter represents the measures a little better than the former, the truth lying between the two.

Fig. 3 represents the square root of the diameter as ordinate with the log. duration of exposure (diminished by a constant) as abscissa, deduced as for fig. 2. It will be seen that the dots thus deduced lie sensibly on a straight line.

$$\sqrt{d} - \sqrt{d_0} = 1{\cdot}03\,(\log t - \log t_0).$$

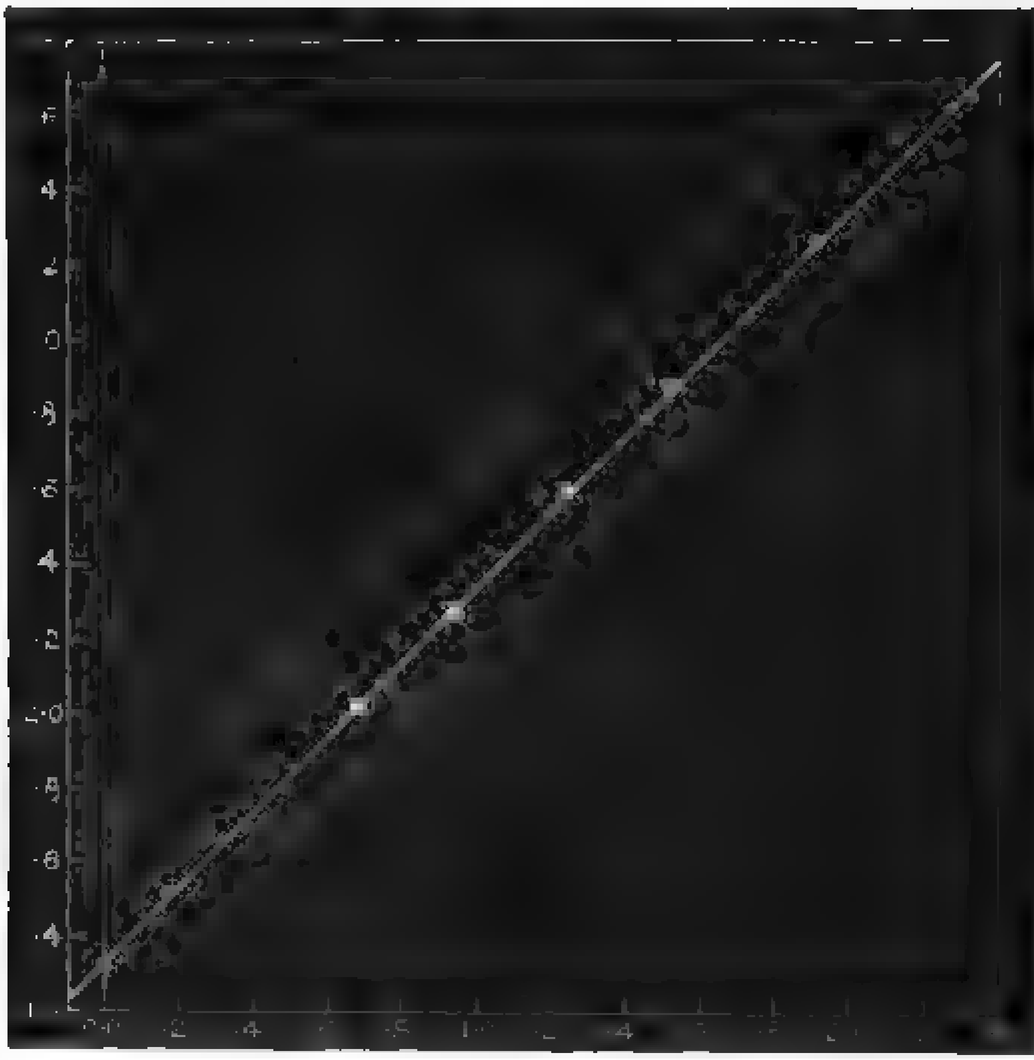
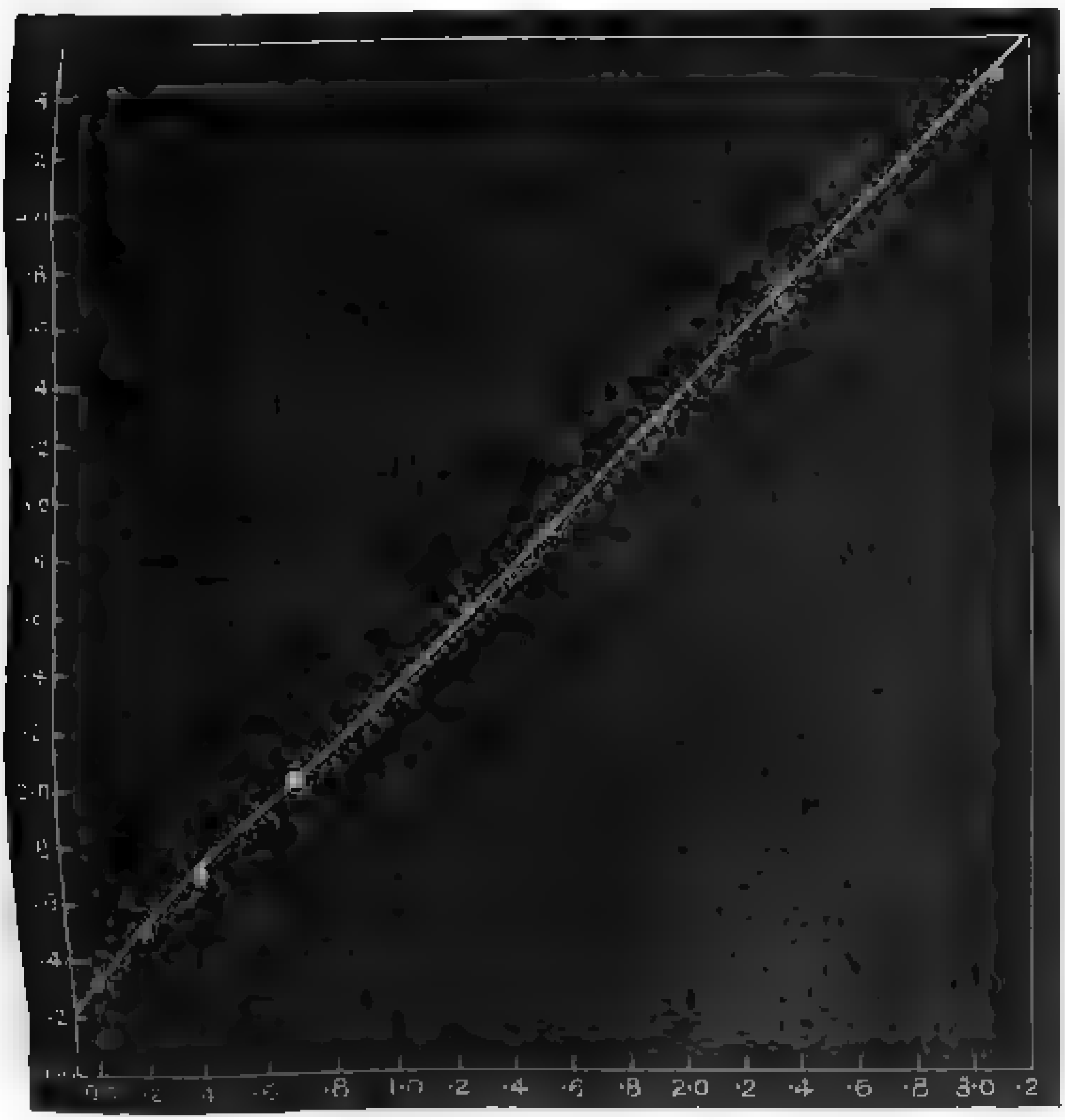


Fig. 4.—The dots exhibit the relation between $\sqrt{\text{diameter}}$ as ordinate and log. duration of exposure (diminished by a constant) as abscissa, the latter being obtained directly from the values for n in the table (Means of Groups). The straight line represents the formula

$$\sqrt{d} - \sqrt{d_0} = 1\cdot03 (\log t - \log t_0).$$



The following table gives the values of $y = \sqrt{\text{diam.}}$ and of $x = \log t - \log t_0$, from which the dots have been plotted, the values of x being obtained by summation of the quantities $\delta x = \frac{\delta y}{n}$, where n is the mean of the preceding and following observed values applicable to the interval δy. The third column shows the values of $x = \frac{y - y_0}{1 \cdot 03}$ from the formula, and the fourth the discordance, calculated−observed, in log t, converted into discordance in magnitude in the last column, by dividing by 0·4.

$\sqrt{\text{Diam.}}$ y	$\log t - \log t_0$ x	$\frac{y-y_0}{1\cdot03}$	Discordance C−O.	
″			in log t	in mag.
1·32	0·000	0·000		
1·51	0·199	0·184	−·015	−·038
1·70	0·394	0·369	−·025	−·062
2·02	0·682	0·680	−·002	−·005
2·29	0·922	0·942	+·020	+·050
2·60	1·216	1·243	+·027	+·068
2·88	1·487	1·515	+·028	+·070
3·27	1·889	1·893	+·004	+·010
3·67	2·322	2·282	−·040	−·100
4·47	3·060	3·058	−·002	−·005
		Mean Discordance	±·018	±·045

Thus the mean discordance between the abscissæ deduced directly from the observations, and those given by the formula, corresponds to less than one-twentieth of a magnitude through a range of eight magnitudes.

II.—*The Relation between Duration of Exposure and Brightness of Star photographed.*

A discussion of the measures of diameters given in the preceding tables compared with the valuable photometric determinations of magnitudes of the 9th and 11th magnitude stars, made at the Oxford University Observatory with Professor Pritchard's wedge photometer, and with Argelander's magnitudes for stars of about the 7th and 9th magnitudes, gives data for determining whether the law that, for equal photographic effects,

Duration of exposure × brightness of object = const.

holds satisfactorily under the conditions and within the limits here considered.

It will be remembered that at the meeting of the Comité de la Carte du Ciel at Paris, in 1889, it was decided that, in order to photograph the 11th magnitude stars, the exposure should be that required for Argelander's 9th magnitude, multiplied by 6·25 (or, rather, 6·31, as it should have been), the intention being to prolong Argelander's scale from mag. 9·0 to mag. 11·0. Since then doubts have been raised as to the validity of this procedure, it being considered that the exposure must be increased in a much higher ratio than 1 to 6·31 to photograph stars fainter by 2·0 magnitudes. The present discussion is directed principally to this point, the photographic images of stars of the 9th and 11th magnitudes being compared with the Oxford photometric magnitudes. As a further check, the photographic images of stars of about the 7th and 9th magnitudes have been compared with Argelander's visual magnitudes, but difficulty has been experienced in obtaining a sufficiency of such stars to eliminate the large accidental errors arising from differences between visual and photographic brightness.

In the following comparison of diameters, the first column indicates the two results compared, denoted by the exposure, and the group in the preceding tables; thus 12_2^s denotes the 12^s exposure in Group II., and similarly in other cases. In the second column the difference of $\sqrt{\text{diameter}}$ for the two exposures compared is given, the values being taken from those for the groups in the above-mentioned tables. The third column gives the log. factor by which the exposure should be multiplied to equalise the two photographic images. Since $\delta(\sqrt{\text{diam.}}) = \delta(\log t)$ very nearly, the log. factor is obtained simply by adding to the difference of the logarithms of exposures the quantities in the second column. The log. factor for 1·0 magnitude is obtained at once by dividing by the difference of magnitudes of the groups compared (nearly 2·0 magnitudes in all cases), and the resulting factor for 1 magnitude is given in the last column, this being the factor by which the duration of exposure should be multiplied to obtain equal photographic effect from a star fainter by 1 magnitude.

Comparison of Diameters of 9th and 11th mag. Stars (Oxford Photometric Magnitudes).

Photo. 128.

s s	$\delta(\sqrt{d})$	Log. factor for 1 90 mag.	Log. factor for 1 mag.	Factor for 1 mag.
$12_2 - 94_3$	−·01	0·88	0·463	2·90
$15_2 - 125_3$	+·04	0·96	0·505	3·20
$20_2 - 187_3$	−·07	0·90	0·474	2·98
$30_2 - 250_3$	−·03	0·89	0·468	2·94
			Mean	3·00

Photo. 178.

s s	$\delta(\sqrt{d})$	Log. factor for 1·93 mag.	Log. factor for 1 mag.	Factor for 1 mag.
$20_1 - 160_3$	+ ·06	0·96	0·497	3·14
$40_2 - 320_4$	+ ·04	0·94	0·487	3·07
$40_1 - 320_3$	− ·09	0·81	0·420	2·63
$80_2 - 640_4$	− ·08	0·82	0·425	2·66
$80_1 - 640_3$	− ·13	0·77	0·399	2·51
				Mean 2·80

Photo. 180.

s s		for 1·96 mag.		
$16_3 - 100_5$	+ ·02	0·82	0·418	2·62
$25_4 - 159_6$	+ ·15	0·95	0·485	3·05
$25_3 - 159_5$	+ ·10	0·90	0·459	2·88
$40_4 - 251_6$	+ ·23	0·03	0·525	3·35
$40_3 - 251_5$	+ ·11	0·91	0·464	2·72
$63_4 - 398_6$	+ ·02	0·82	0·418	2·62
$63_3 - 398_5$	+ ·14	0·94	0·480	3·02
				Mean 2·89

Photo. 181.

s s		for 1·96 mag.		
$16_3 - 63_5$	+ ·03	0·63	0·321	2·09
$25_4 - 100_6$	− ·03	0·57	0·291	1·95
$25_3 - 100_5$	+ ·05	0·65	0·332	2·15
$40_4 - 100_6$	+ ·08	0·48	0·245	1·76
$40_4 - 398_6$	− ·28	0·72	0·367	2·33
				Mean 2·06

s s				
$40_3 - 100_5$	+ ·28	0·68	0·347	2·22
$40_3 - 398_5$	− ·06	0·94	0·480	3·02
$63_4 - 398_6$	+ ·03	0·83	0·423	2·65
$63_3 - 398_5$	+ ·11	0·91	0·464	2·91
$100_4 - 631_6$	+ ·20	1·00	0·510	3·24
$100_3 - 631_5$	+ ·18	0·98	0·500.	3·16
				Mean 2·87

Photo. 185.

s s		for 1·96 mag.		
$16_5 - 100_6$	− ·16	0·64	0·327	2·12
$25_5 - 159_6$	− ·05	0·75	0·383	2·42
$40_5 - 251_6$	− ·04	0·76	0·388	2·44
s m s				
$251_5 - 41{\cdot}52_6$	− ·14	0·86	0·439	2·75
				Mean 2·43

Comparison of Diameters of 7th and 9th mag. Stars (Argelander's Magnitudes).

Photo. 185.

Groups II. and IV. consist of Stars photographically bright as compared with their visual magnitudes.

s s	$\delta(\sqrt{d})$	Log. factor for 1·78 mag.	Log. factor for 1 mag.	Factor for 1 mag.
$16_2 - 100_4$	+·10	0·90	0·506	3·21
$25_2 - 159_4$	+·08	0·88	0·494	3·12
$40_2 - 251_4$	+·10	0·90	0·506	3·21
m s $251_2 - 41{\cdot}52_4$	−·22	0·78	0·438	2·74
				Mean 3·07
		for 1·97 mag.		
$16_3 - 100_5$	−·02	0·78	0·396	2·49
$25_3 - 159_5$	−·06	0·74	0·376	2·38
$40_3 - 251_5$	−·08	0·72	0·365	2·32
m s $251_3 - 41{\cdot}52_5$	−·44	0·56	0·284	1·92
				Mean 2·28

Taking the means for each photograph (181 being divided into two groups of diameters under and over 2″·1 respectively) we have

Photo.	Factor for 1 magnitude. Oxford photom.	Argelander	Diff. of Mag. for Factor 2·512 Oxford photom. mag.	Argelander mag.
128	3·00	...	0·839	...
178	2·80	...	0·895	...
180	2·89	...	0·868	...
181_1	2·06	...	1·274	...
181_2	2·87	...	0·873	...
185	2·43	3·07	1·036	0·821
185		2·28		1·117
Means	2·675	2·675	0·964	0·969

It appears that whether we take the Oxford photometric magnitudes or Argelander's, the factor 2·512 for the exposure gives 1·0 magnitude within the limits of accidental error.

Considering the large differences between photographic and visual brightness in the case of individual stars (amounting probably in some instances to nearly ± 1 magnitude) and the accidental variations in atmospheric or instrumental tremors, in the state of the sky, in incipient dew on the object glass, and in sensibility or development of different parts of the photographic film, the discordances in the individual results for the factor are not surprising, and the mean value agrees quite as closely with the law

$$\text{Exposure} \times \text{brightness} = \text{const.}$$

as could be expected.

It is curious, however, that Photo. 181 gives a markedly large factor for the smaller diameters, indicating that the first faint images of 11th magnitude stars were more readily obtained relatively to those of the 9th magnitude stars than the denser images, and Photo. 185 to a certain extent gives a similar result. Both these photographs, which, it may be remarked, were taken in moonlight, show small sharp images even of the faintest stars.

Similar conclusions result from an examination of the images visible on the photographs, made by myself with an achromatic magnifying lens of about 1-inch focus, and tabulated before the plates were measured. In the following table the images visible on Photos. 178, 180, and 181 are indicated by the corresponding exposure, in italics when the image was only faintly visible, in ordinary type when it was fairly distinct, and in heavy type when it was unmistakeable, at a glance, and accurately measurable for diameter. The images with longer exposures were, of course, also visible, but there is no occasion to note them.

Exposures giving Images of 9th and 11th mag. Stars on Photographs of the District round 36 Pegasi.

Star's No.	Magnitude Photom.	Magnitude Arg.	Photo. 178.		Photo. 180.			Photo. 181.		
			s	s	s	s	s	s	s	s
1	8·6	8·7	...	**20**	...	10	**16**	...	...	**16**
2	8·9	9·2	20	**40**	...	10	**16**	...	...	**16**
3	9·0	9·3	20	**40**	...	*10*	**16**	...	...	**16**
4	9·0	9·1	...	**20**	...	10	**16**	...	...	**16**
5	9·0	9·1	...	**20**	...	10	**16**	...	...	**16**
6	9·1	9·3	*20*	**40**	...	...	**16**	...	...	**16**
7	9·1	9·0	...	**40**	...	16	**25**	...	16	**25**
8	9·2	9·1	*40*	**80**	...	16	**25**	*16*	*25*	**40**
9	9·2	9·4	80	...	...	25	**40**	...	*16*	**25**
10	9·3	9·2	80	...	...	16	**25**	...	...	**40**
11	9·3	9·2	...	**40**	*16*	25	**40**	...	...	**16**
12	9·4	9·3	*40*	**80**	...	40	**63**	...	25	**40**
13	10·8	...	*80*	**160**	...	*63*	**100**	*40*	63	**100**
14	10·8	...	...	**160**	...	*63*	**100**	...	40	**63**
15	10·8	...	*160*	**320**	...	*63*	**100**	*40*	*63*	**100**
16	10·9	...	80	**160**	...	63	**100**	...	63	**100**
17	10·9	...	...	**320**	...	*63*	**100**	*40*	63	**100**
18	10·9	...	*160*	**320**	...	63	**100**	...	63	**100**
19	11·0	...	*80*	**160**	...	*63*	**100**	*40*	63	**100**
20	11·0	...	*160*	**320**	...	*63*	**100**	...	*63*	**100**
21	11·1	...	*160*	**320**	...	**100**	**159**	...	...	**100**
22	11·2	...	...	**320**	...	100	159	...	*63*	**100**
23	11·2	...	...	**320**	...	100	**159**	...	*63*	**100**
24	11·3	...	160	**320**	...	*159*	**251**	...	*100*	**159**

It thus appears that this independent examination fully confirms the results deduced from the measures, particularly in the case of Photo. 181. It is remarkable that on this photograph (taken in moonlight) some 11th magnitude stars were impressed faintly in 40^s, and nearly all in 63^s. Measurable images of all stars down to 11·0 magnitude were obtained in 100^s, both on this photograph and on No. 180. On the other hand, about three times the exposure was required on Photo. 178, a fact which may be explained by a slight dimming of the object glass by dew, noticed by the observer a little time after this photograph was taken.

The results of this discussion may be thus summarised:—

Putting d=diameter (in seconds of arc) of the image of a star of magnitude m (Pogson's scale) with the exposure t (in seconds of time), we have—

I. For the same star with different exposures,

$$\sqrt{d} = 1{\cdot}03 \log t + \text{const.} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

an empirical formula which represents the observations through a range of eight magnitudes with a mean apparent error of only $\pm$ 0·018 corresponding to $\pm$ ·045 mag.

II. For equal diameters

$$\text{Exposure} \times \text{brightness} = \text{const.}$$

or

$$0{\cdot}4 \times m = \log t + \text{const.} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The relation actually found is

$$0{\cdot}4 \times m = 0{\cdot}97 \log t + \text{const.},$$

which is sensibly the same as (2).

III. From (1) and (2) it follows that, for the same exposure, the relation between diameter of image and magnitude of star is

$$0{\cdot}4 \times m = \text{const.} - \frac{\sqrt{d}}{1{\cdot}03}$$

or

$$m = \text{const.} - 2{\cdot}43 \sqrt{d} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

that is,

$$\text{Magnitude of star} = \text{const.} - 2{\cdot}43 \times \sqrt{\text{diameter.}}$$

The constants are, of course, different in the different cases. In (1) the constant would be different for stars of different magnitudes; in (2) for stars of different diameter; and in (3) for stars with different exposures. They would also, of course, be slightly different for different plates.

Combining (1), (2), *and* (3) *in one formula, we have*

$$m = 2{\cdot}5\,(\log t - 0{\cdot}97\sqrt{d}) + \text{const.} \quad . \quad . \quad . \quad . \quad (4)$$

which may be considered as replacing the approximate empirical formula given in the "Monthly Notices" for March, 1891, *vol. li. p.* 284.

Royal Observatory, Greenwich:
1892 *January* 8.

On the Observations for Coincidence of the Collimators through the Cube of the Transit Circle at the Royal Observatory, Greenwich (II). By H. H. Turner, M.A., B.Sc.

In a former paper (*M.N.* vol. xlvi. p. 329) I referred to the fact that when observations for coincidence of the collimators at the Royal Observatory were made by viewing the South Collimator with the North through eight holes of sector form cut in the central cube of the transit circle, the readings were found to differ systematically from those obtained when the view was unobstructed; and I detailed a series of simple experiments which seemed to show that this phenomenon was purely optical. This conclusion has been confirmed by an interesting and elaborate series of experiments by Dr. Wislicenus at Strasburg. (*Ast. Nach.* No. 3067). He states his chief conclusions as follows:—

1. The systematic differences found at Greenwich are purely of an optical nature, and can be obviated by making the hole in cube circular and larger than the object-glasses of the collimators.

2. If the object-glass of a telescope be obscured by concentric discs or rings quite symmetrically, or by symmetrical screens of other forms, such as the radial bars at Greenwich, not only is the character of the focal image altered, but it *may* be displaced laterally.

With regard to the excellent though somewhat obvious suggestion in (1), it may be remarked that there are practical difficulties in the way of adopting it in the case of the Greenwich transit circle; but the point should not be lost sight of in designing a new instrument.

With regard to conclusion (2), Dr. Wislicenus lays some stress on the word *may*. He is inclined to attribute such lateral displacements to residual chromatic and spherical aberrations, which make the actual focus of an object-glass somewhat indefinite. Instead of a bright point we get in fact a short line of light along the optical axis, the brightest point of which is selected for focussing. Cutting off some of the rays, however symmetrically, will cause a different point of this line to be selected, and for all but central pencils we shall thus get a paral-

lactic effect. The suggestion is of value, and it will be seen that paragraph (ι) in what follows seems to distinctly support it.

The subject having thus attracted attention elsewhere, and having possibly an important bearing (as Dr. Wislicenus remarks) on heliometer and other observations where object-glasses are sometimes screened, I have thought it advisable to communicate to the Society some further notes which I put together some years ago, but which were laid aside at the time because of the negative character of some of the conclusions, which may be summarised as follows:—

(I.) The systematic difference under discussion, after remaining constant for several years, began to change, and numerically doubled itself. At present there are signs of its returning towards the smaller values.

(II.) No cause can be assigned with certainty for this change. Either the figures of the object-glasses have slightly changed, or, possibly, adopting the above suggestion of Dr. Wislicenus, the eccentricity of the pencil has been changed, and the parallactic effect consequently increased.

(III.) The effect which should be traced on stellar observations is found to be extravagantly too large, pointing to some other disturbing cause.

I proceed now to give the notes nearly as they were drawn up in 1888:—

(α) "Experiments on the effect of the limitation of aperture of the collimators when observations are taken through the central cube of the transit circle having led to the suspicion that the object-glasses of the collimators might be defective, they have been examined by Mr. Simms, who has reported that they are excellent." (*R.A.S. Council Report*, Royal Observatory, Greenwich, 1887, February; *M.N*, vol. xlvii. p. 149). We are thus not dealing with any defect such as a good optician eliminates in constructing object-glasses.

(β) It is probable that any form of screen would produce some effect on the reading for coincidence. A few experiments were made, not on the two collimators, but with the transit-circle telescope on each of them, using a screen to cover half the object-glass, as follows:—

T.C. on North Collimator.

Date.	Observer.	Whole O.G.	Excess of Reading of T.C. micrometer with Screen covering Upper half.	Lower half.	E. half.	W. half.
1886.			r	r	r	r
Apr. 20	H. T.	...	·000	−·009	+·006	+·047
1887.						
Feb. 29	H. T.	...	·000	+·004	−·005	+·154
29	H. T.	...	·000	−·013	−·024	+·108
Mar. 3	H. T.	−·004	·000	+·012	+·010	+·082
3	H. T.	+·003	·000	−·004	−·010	+·035

T.C. on South Collimator.

Date.	Observer.	Whole O.G.	Excess of Reading of T.C. micrometer with screen covering Upper half.	Lower half.	E. half.	W. half.
1886.			r	r	r	r
Apr. 20	H. T.	...	·000	·000	−·013	+·014
1887.						
Feb. 29	H. T.	...	·000	−·014	−·025	+·037
29	L.	...	·000	−·021	−·029	+·036
Mar. 3	H. T.	+·012	·000	−·023	−·018	+·019
3	H. T.	−·001	·000	−·018	−·004	+·011

1 rev. of the micrometer = 14″·78.

(γ) The discordance between readings for coincidence of collimators through the cube and with unobstructed view has undergone a curious change in the course of years. The following is a complete list of the mean annual values to date:—

1871	0″·58	1878	0″·53	1885	0″·99
1872	·56	1879	·56	1886	1·14
1873	·56	1880	·61	1887	1·19
1874	·56	1881	·80	1888	1·02
1875	·53	1882	·73	1889	1·21
1876	·53	1883	·87	1890	1·21
1877	·61	1884	·77	1891	0·87

The value was thus sensibly constant for ten years, but has since either been continuously changing, or has suffered two more or less abrupt changes about 1881 and 1885. The following paragraphs give the results of the examination of various hypotheses which might account for this change or changes.

(δ) *Change of Observer.*—It is possible that personality may have some influence on the result. Below are two sets of results collected according to separate observers:—

1877–1879.	No. of Obs.	Discordance.	1882–1887.	No. of Obs.	Discordance.
Lynn	22	0″·58	Lewis	38	1″·07
Criswick	11	·46	Hollis	61	0·85
Downing	27	·65	Downing	76	0·95
Thackeray	16	·48	Thackeray	13	1·23

Two observers are common to the two sets, and the changes are apparently independent of the observer.

(ϵ) *Introduction of the Reversion Prism Eyepiece.*—The observations in earlier years had not been reduced in the first instance, and attention was therefore drawn only to the change in 1885. It was at once suspected that this might be due to the introduction of the reversion prism eyepiece, and observations to

compare this with the ordinary eyepiece previously in use were made as follows:—

On 1888 March 1 I took the following readings of N. Coll. on S. Coll. through the cube:—

R.P. Eyepiece. r	R.P. Eyepiece. l	Mean.	Ordinary Eyepiece.	Diff. in rev.	Diff. in arc.
r	r	r	r	r	"
·685	·704	·695	·696	+·001	+0·02
·668	·701	·685	·690	+·005	+0·12
·665	·697	·681	·691	+·010	+0·24

Each number in columns 1 and 2 is the mean of three, and in columns 3 and 4 of six observations.

On 1888 March 12 readings were also taken by all the four regular observers with both eyepieces, and both through the cube and with instrument raised, as follows:—

Observer.	Excess of reading through Cube. R.P. Eyepiece.	Ordinary Eyepiece.	Diff. R.P.—O.
	"	"	"
H. T.	+1·11	+1·40	−0·29
A. D.	+0·87	+0·90	−0·03
T.	+0·24	+0·99	−0·75
L.	−0·22	+0·31	−0·53
H.	+0·44	+0·65	−0·21
Mean	+0·49	+0·85	−0·36

Thus the correct use of the R. P. eyepiece will certainly not explain an *increase* in the discordance.

(ζ) It was suspected, however, that the position of the prism in front of the aperture of the eye-lens might have some influence on the results. It had occasionally been found out of adjustment, being held only by a single screw, round which as a centre it was liable to be rotated. The limit of displacement which might be unnoticed by the observer is, on one side a position when enough light comes through the uncovered portion of the eye-lens to give a second image of the field of view (1); and on the other side a position where some phenomenon of total reflexion occurs and the field becomes quite dark (2). Between positions (1) and (2) is that of good adjustment, which we may call (3). On 1888 March 12 the following observations of N. Coll. on S. Coll. were taken with the prism in these three positions.

Observer.	Reading of N. Coll. Micr. Position (1).	Position (3).	Position (2).
	r	r	r
H. T.	·664	·660	·645
H. T.	·665	·667	·634
H. T.	·663	·670	·636
L.	·618	·615	·605
H.	·616	·623	·596
Mean	·645	·647	·623

Thus if the prism is out of adjustment towards the position (1) the readings are not sensibly affected, but towards the position (2) the readings of N. Coll. micr. are spuriously diminished. Thus, as before, an *increase* in the discordance under examination cannot be explained by bad adjustment of the prism.

(η) *Changes of position of the Collimators with reference to the Central Cube.*—The most important change in the mounting of the collimators was made early in 1882, when they were mounted on two pivoted stalks so that they could be turned aside to allow of a greater range of reflexion observations with the transit circle. An inspection of the annual results for the years immediately preceding and following 1882 shows that this change did not affect the discordance under discussion. There have been, however, slight changes in relative azimuth, and possibly slight lateral shiftings of the axis of one or all three telescopes. After the Y's of the transit circle telescope had been taken out and cleaned early in 1888, it was found that the telescope went back into a sensibly different position, closer to its western pier, towards which it is pressed by a spring. Small pieces of dirt had been accumulating for years on the western bearing, and the removal of these allowed of a slight lateral shift. This of course would alter the exact position of the interposed cube with reference to the collimator object-glasses.

Changes in relative azimuth, both periodic and secular, are known to occur, though their total amount is very small—probably less than a minute of arc; and it does not seem likely that changes of this magnitude would affect the results. But both these possible causes were considered.

(θ) *Lateral Shiftings.*—The wooden model of the cube was alternately placed in two positions separated by about ½-inch in the E. & W. direction, and readings of the transit-circle micrometer were taken for coincidence with the N. Collimator on 1888 March 15.

Observer.	No. of Obs.	Cube. East.	Cube. West.	E.−W.	In arc.
		r	r	r	"
H. T.	10	·331	·348	−·017	−0·25
H. T.	10	·364	·372	−·008	−0·12
H. T.	10	·356	·361	−·005	−0·07
H.	10	·304	·340	−·036	−0·53
H.	10	·310	·352	−·042	−0·62
Mean		·333	·355	−·022	−0·32

There seems to be, therefore, a small effect due to lateral shift; but half an inch is probably a much larger quantity than any which occurred in actual fact.

Under this head I may remark that observations are some-

times made through the cube with the transit-circle telescope pointing vertically upwards instead of vertically downwards. Any slight want of symmetry of the aperture with respect to the optical axis of the collimators might cause a difference between the two methods. Observations by Mr. Miskin on 1891 December 29 seem to show that there is no sensible difference. Mean readings of N. Coll. micr. as follows:

	O.G. up.	O.G. down.
	r	r
	·566	
		·568
	·603	
		·600
	·581	
Mean	·583	·584

Each number being the mean of six readings.

(ι) *Changes of Azimuth.*—The wire system in each of the collimators consists of two pairs of wires at right angles, forming at their crossing a square whose side is about 85″. If the discordance under consideration vary with the position in the field of view (as would follow, for instance, from Dr. Wislicenus' suggestion), it should be different for bisections made with opposite sides of the squares, which is equivalent to changing the relative azimuth by 170″—a much larger quantity than could correspond to any secular change. The following comparisons were made on 1888 March 12:

Observer.	No. of Obs.	Right of Square.	Left of Square.	Diff.	Diff. in arc.
		r	r	r	″
H. T.	10	+0·094	+0·083	+0·011	+0·26
H. T.	10	+0·072	+0·042	+0·030	+0·73
H. T.	10	+0·074	+0·045	+0·029	+0·70
T.	6	+0·082	+0·072	+0·010	+0·24
H. T.	10	+0·057	+0·058	−0·001	−0·02
H. T.	10	+0·041	+0·031	+0·010	+0·24
Mean		+0·070	+0·055	+0·015	+0·36

From 1877 to 1882 the common azimuth of the collimators was nearly always less than 10″ from the meridian. At the end of 1882 the screws of the S. Coll. apparently got loose, and the deviation from the meridian became large and irregular. The screws were tightened on 1883 May 9. Since then the azimuth of the S. Collimator has gradually changed, as follows:

$\overset{''}{7}$ at the end of			1883
22	"	"	1884
22	"	"	1885
26	"	"	1886
40	"	"	1887

On 1888 January 18 the object-glasses of the collimators were taken out and cleaned. On restoring them the azimuth of the S. Coll. was found to be reduced to 30″.

It was

$\overset{''}{27}$ at the end of			1888
24	"	"	1889
27	"	"	1890
20	"	"	1891

The removal of the object-glasses for repolishing in 1891 August did not affect the continuity of the results.

There were new wires inserted in

N. Coll.	S. Coll.
on 1874, June 29	1874, Nov. 9
1881, Jan. 31	1882, Dec. 25
1884, June 16	1883, March 13

(κ) *The Effect of the Discordance on Stellar Observations.*—An erroneous determination of collimation would involve erroneous level, azimuth, and clock errors. It is easy to show that an error of c'' in collimation ultimately affects the R.A.'s of stars by $\frac{c}{15}^{\text{sec}}$ tan $\frac{1}{2}$ N.P.D. Now the observations for collimation have been partially corrected for the discordance under consideration, adopting the numerical value deduced from observations in the early years. For various reasons this constant was not changed even when it was found that the mean annual value of the discordance had increased to nearly twice its original amount. Thus the R.A.'s of stars in the years subsequent to 1880 should be increased by k tan $\frac{1}{2}$ N.P.D., where k may be taken as $0^{s}\!\cdot\!008$ for 1881–1884, and $0^{s}\!\cdot\!020$ for 1885–1890. To test the reality of this correction, a comparison of the R.A.'s of stars deduced from observations above and below pole in the years 1877–1883 was made, and a similar comparison for the years 1885–6. The difference between the two series should require a correction readily deducible from the above theoretical expression, and tabulated in the fifth column of the following table. It will be seen that the observed differences are extravagantly larger than the theoretical, although of the same sign; and point to some other disturbing cause.

Limits of N.P.D.	Mean Excess of R.A. above Pole. 1877–1883.	1885–6.	Diff.	Theoretical difference.
° °	s	s	s	s
1– 5	+·555	+·269	+·286	+·001
5–10	−·047	−·244	+·197	+·003
10–15	−·139	−·253	+·114	+·005
15–20	+·264	−·244	+·508	+·006
20–25	+·005	−·141	+·146	+·007
25–30	−·001	+·002	−·003	+·009
30–35	+·026	−·077	+·103	+·011
35–40	+·023	−·063	+·086	+·013
40–45	+·005	−·155	+·160	+·015
45–50	−·019	−·069	+·050	+·017

On the other hand, the reflexion observations seem to agree well with theory. These are discussed annually, as "Corrections to Adopted Level Errors," in the Greenwich volumes; and the weighted mean correction for the years 1882–3 is $-0''\cdot28$, while that for 1885–6 is $+0''\cdot19$, exceeding the former by $+0''\cdot47$. According to the formula given above, this quantity should be $+0'\cdot57$.

A New Photographic Photometer for determining Star Magnitudes. By W. E. Wilson.

I would like to bring before the notice of the Society the design of an instrument which I think will be of use in stellar photography, and especially in determining photographic magnitude of stars.

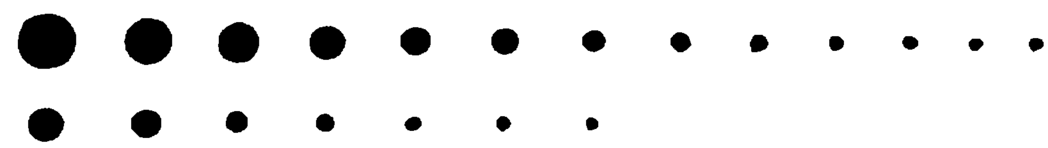
The instrument consists of a photographic plate and holder ($6\frac{1}{2}$ in. × 1 in.), moving in a slide in the direction of its greatest length. A spiral spring tends to pull the holder to one end of the slide, and a simple electro-magnetic escapement each time the magnet is excited allows the spring to advance the plate and holder $\frac{1}{10}$ inch. The entire apparatus screws into the eye-end of a photographic telescope.

A star whose magnitude is to be determined is focussed close to the end of the photo plate, and an exposure of say 100^s given. The magnet is then excited for a moment by the current from a contact-maker, driven by a clock; the plate moves forward suddenly $\frac{1}{10}$ inch, and a second exposure is given, which lasts only 63^s. Again the plate moves forward to give a third exposure of $39^s\cdot8$, and the exposures are thus continued in the above ratio until they are reduced to 1^s. The telescope is then set on a standard star, such as *Polaris*. The holder is moved back to its original position, and *Polaris* is placed $\frac{1}{10}$ inch below

the first exposure of star No. 1. The same series of exposures are then given, and the plate developed. The result will be like this:—

Polaris =

Star No. 1 =



The relative number of images of the two stars will give their magnitudes to 0·5. The times of exposures will vary as the number whose log. is 0·2, but there is no reason why they should not be made to give 0·1 magnitudes.

The contacts are made by a wooden disc, revolving uniformly by the driving clock of the equatoreal. On its edge are brass pins, which are placed so as to pass under a wiper at the correct intervals. The entire process is automatic once the star is set in its right place. Each plate will hold ten sets of exposures.

The instrument will also be of use for determining the actinic value of the sky before taking a stellar photograph. In this case, by taking a series of *Polaris*, and finding thus at what exposure it fails to record itself, the exposure necessary to record a star of another magnitude will be known.

Also, to determine the value of wire screens in front of the O.G., a series can be taken with and without the screen and the necessary value found.

I hope to exhibit some negatives taken with the instrument shortly before the Society.

1892 *January* 3.

The Red Stars in the Great Perseus Clusters.
By the Rev. T. E. Espin, B.A.

Although the fact that there are several red stars in G.C. 512,521 is well known, as far as I am aware their actual places have never been published, with the exception of one or two of the brighter ones. Herschell and D'Arrest each saw one, Smyth two, Birmingham three, Rev. T. W. Webb five, Rev. T. T. Smith eight. The "Observations of Nebulæ and Clusters at Birr Castle" (*Scientific Transactions of the Royal Dublin Society*, vol. ii., New Series, p. 27) mention five. As there seemed to be considerable divergence of opinion as to their number, the clusters were carefully examined on the nights of 1891 December 29 and 1892 January 1. The powers used were the sweeping power of 70, and a power of 200. The first night was remarkably fine, and the definition superb, and the sky intensely black. While examining the P cluster (G.C. 512) I had a strong suspicion that the N.P. part was nebulous. The eye-pieces were carefully cleaned,

and the telescope moved rapidly backwards and forwards, and a decided impression was left upon my mind that there is really some faint nebulosity in that part. The second night, January 1, the definition was poor, and no nebulosity was seen. No red stars were seen in G.C. 512, four lie between the clusters, three are found in G.C. 521, the remaining two among the outliers. The spectroscopic observation of the stars in the cluster is difficult, the spectra overlapping each other. The stars are all third type, and very similar to one another; the colours are nearly similar, the magnitudes also. The following table gives the D.M. number of the stars, the place, the D.M. magnitude, the observed magnitude, and the spectrum :—

	D.M.	R.A. II h. (1855)	Decl.	Magnitude. D.M.	Magnitude. Observed.	Colour.	Spect.
	°	m s	° ′				
(1)	+56 512	8 40	+56 45·2	9·0	8·8	OR	III.
(2)	56 547	10 19	56 19·4	8·2	7·6	OR′	III.!
(3)	56 551	10 45	56 29·3	8·2	7·8	OR	III.
(4)	57 550	11 26	57 11·1	8·5	8·5	OR	III.
(5)	55 597	11 58	55 56·2	8·2	7·0	OR	III.!
(6)	56 583	12 12	56 26·3	8·6	8·2	OR′	III.
(7)	56 595	12 57	56 32·0	8·5	8·4	OR′	III.
(8)	56 597	13 9	56 32·7	8·6	8·5	OR	III.!
(9)	56 609	15 3	56 46·8	8·4	8·8	OR	III.!

It is obvious that the observed magnitudes are overrated, and, rejecting No. 2 and No. 5, a correction of +0·2 is found. No. 2 seems to be actually underrated in Argelander. Mr. Pihl, in *The Stellar Cluster χ Persei*, makes it 7·8, and in the *Neue Annalen der k. Sternwarte in Bogenhausen*, Band ii., in a study of 38h. *Persei*, Dr. Oertel gives it as 7·6. As regards the star No. 5, I suspect from the great difference of magnitude that it may be variable. The first observation of it was on December 22, when it was rated as 7·0; on December 29 it was again observed, and compared with No. 2, when it was estimated as 7·4. On both nights the fainter stars were carefully examined, and, had there been any other red star above magnitude 10·5, it could not have escaped detection.

Tow Law:
1892 *January* 6.

On the Phenomenon of the Transit of the First Satellite of Jupiter 1890 September 8, and Observations of the Red Spots on the Planet. By E. E. Barnard, M.A.

In a letter which I have received from Mr. A. Stanley Williams he informs me that he has sent a communication to the Royal Astronomical Society in which he endeavours to explain the apparent duplicity of the first satellite of *Jupiter* at its transit 1890 September 8, by supposing the phenomenon to have been a close conjunction of the satellite with a small spot which he had seen three days earlier on the planet.

Leaving aside the fact that it is wholly improbable that two experienced observers should have been so mistaken in a matter of this kind, I would say that the phenomenon of apparent duplicity was watched for upwards of half an hour before the visitors interrupted (from before sidereal $18^h\ 30^m$ to about $19^h\ 7^m$), part of which time Mr. Burnham observed with me. During that interval no relative motion was detected. At the transit of I, the relative motion of the satellite and a spot on *Jupiter* would have amounted to $0''\cdot15$ each minute of time—a displacement which would have been only too apparent in a few minutes with the 12-inch and the high magnifying power employed. It is, therefore, apparent that Mr. Williams's explanation can have no bearing on the apparent duplicity of Satellite I at its transit 1890 September 8.

I consider the observation of the double transit an important one, the explanation of which will perhaps be still more important.

It should be accepted as unquestionable that the phenomenon of 1890 September 8 was wholly connected with the satellite. One or the other of the two probable explanations which I have given in *Monthly Notices*, No. 9, vol. li., will doubtless be found in the end to be the true solution of the matter. It is unfortunate that the transits of this object still occur over a dark portion of *Jupiter*. As soon as these are transferred to a bright region we may expect to know something more definite.

The New Red Spot in the Southern Hemisphere.

The new red spot, which has been such a striking feature in the southern hemisphere of *Jupiter* during the past opposition, has disappeared. About the last of October it was the most prominent feature on the planet. It was well defined and of a clear red, very much resembling in distinctness and colour the appearance of the great red spot in 1880. In the first part of November it began to fade quite rapidly, and by the 20th was scarcely discernible.

On December 14 no trace of it could be made out with any certainty.

On November 20, $8^h\ 2^m.0$, Mount Hamilton mean time, it was in transit, and its longitude was $110^\circ{\cdot}9$.

The Great Red Spot.

This object seems again to be slackening its rate of rotation. During the past opposition its longitude remained quite constant at about 3°. Its longitude is now increasing. A transit on December 14, $5^h\ 5^m.3$, gave the longitude $= 6^\circ{\cdot}4$. It is now very much more conspicuous than at opposition, and is a stronger red in colour.

Mount Hamilton:
1891 *December* 17.

Reappearance of Saturn's Ring, and Position Angle before the disappearance, observed at the Observatory, Utrecht. By Professor J. A. C. Oudemans.

The telescope of the Utrecht Observatory has an object-glass of Jacob Merz, aperture 0·260 metre; focal distance 3·200 metres. The eyepiece employed was a positive one of Steinheil, with a magnifying power of 162.

1891 October 28, 18^h, M. T., Utrecht. Hazy. *Saturn* decidedly without ring.

1861 October 29, $17^h\ 30^m$. M. T., Utrecht. Clear. *Saturn* decidedly without ring. A thin dark line crosses the disc along the equator.

1891 October 30, 16^h–19^h. Overcast.

1891 October 31, $17^h\ 30^m$. Clouds. *Saturn* visible for a moment; at both sides the ring is visible as a thin bright line.

1891 November 1, 17^h–19^h. Overcast.

1891 November 2, $17^h\ 15^m$. M. T., Utrecht. Clear; a little hazy. Ring clearly visible; very beautiful, with the feeblest magnifying power 114. The dark line across the planet still visible. It seems to me that this dark line must be the dark ring.

I give these observations without comment, judging it better to wait for other observers' results.

After a careful discussion I adopted for the fourth edition of Kaiser's *Sterrenhemel* the following values of the dimensions of *Saturn* and his rings at the mean distance 9·53885 (see that Work, ii. p. 701):

	Diameter.	Semidiameter.
Outer ring, exterior	$39''.5$	$19''.75$
Inner ring, interior	27.5	13.75
Dusky ring, interior	21.8	10.9
Equatorial	17.3	8.65
Polar	15.4	7.7

If the mass of the bright rings is supposed to be $\mu \times$ the mass of the planet, and if the ring's density is supposed to be the same as *Saturn's*, we deduce from these numbers that the thickness of these rings is $3''.82\ \mu$.

$$\text{With } \mu = \frac{1}{118} \text{ (Bessel)} \qquad \text{this becomes } 0''.0324$$

$$\text{,,} \quad \mu = \frac{1}{314} \text{ (H. Struve)} \quad \text{,,} \qquad \text{,,} \qquad 0''.0121$$

The Sun, seen from *Saturn*, presents itself as a disc of $32' : 9.53885 = 3'.355$, and the distance of the interior diameter of the interior bright ring being $13''.75 - 8''.65 = 5''.1$, as long as both the sides of the ring have sunshine,* the remaining shadow of the rings on the planet is

$$\left.\begin{matrix} 0''.0324 \\ \text{or } 0.0121 \end{matrix}\right\} - 5''.1 \sin 3'.355 = \left.\begin{matrix} 0''.0324 \\ \text{or } 0.0121 \end{matrix}\right\} - 0''.0050 = \left\{\begin{matrix} 0''.0274 \\ \text{or } 0.0071 \end{matrix}\right.$$

whereas, according to Bessel's elements, adopted in the *Nautical Almanac*, the earth's elevation above the ring's plane was

on Oct. 28	18^h M.T.Gr.	1°	$57'.7$
Nov. 2	18 ,,	2	8.5

We will take the mean $2^\circ\ 3'.1$; so the breadth of the dusky ring near to the centre of the planet is $2''.85 \sin. 2^\circ\ 3'.1 = 0''.102$; however small this number be, it is much larger than either $0''.0274$ or $0''.0071$, the breadth of the ring's shadow on the planet, adopting either Bessel's or H. Struve's mass of the ring.

* The Sun's elevation changes $18'.4$ in 20 days, *i.e.* $0'.92$ in a day, so the time during which both sides of the ring have sunshine is about $3\frac{1}{2}$ of our days.

Position-Angles of the Ring, measured with the wire micrometer.

1891.	M.T. Utrecht. h m	Pos. Angle. ° ′	Naut. Alm. ° ′	Corr. of N.A. ′
June 24	8 57·5	−5 15·0 (5)	−5 34·7	+19·7
26	8 44·7	−5 11·0 (4)	−5 34·1	+23·1
28	8 51·5	−5 6·5 (5)	−5 33·45	+26·95
July 4	8 43	−5 48·0 (5)	−5 31·4	−16·6
5	8 37·5	−5 26·5 (5)	−5 31·0	+ 4·5
10	8 24·6	−5 41·5 (3)	−5 29·0	−12·5
July 1	12 43·1 = 12 22·6 M.T.Gr.	−5 24·7	−5 32·3	+ 7·6

The numbers in brackets indicate the numbers of measures, which, however, have not been taken into account in deducing the mean.

Utrecht:
1891 *December* 14.

Observations of Occultations of Stars by the Moon, and of Phenomena of the Satellites of Jupiter and Saturn, made at Mr. E. Crossley's Observatory, Bermerside, Halifax, in the year 1891. By J. Gledhill.

Lunar Occultations.

1891 January 17.—ξ *Arietis.* Disappearance, G.M.T., $11^h\ 3^m\ 20^s.5$. Time by *N. Almanac*, $11^h\ 5^m$. Definition not good.

1891 March 26.—l^2 *Virginis.* Disappearance, $10^h\ 3^m\ 8^s$. Time by *N. Almanac*, $10^h\ 1^m$. Stormy.

1891 April 18.—42 *Leonis.* Disappearance, $10^h\ 27^m\ 56^s$. Time by *N. Almanac*, $10^h\ 35^m$.

Phenomena of Jupiter's Satellites, observed with the 9⅓-inch Cooke Equatorial Refractor.

Date.	Satellite and Phenomena.		G.M.T. of Observation.	Time by Nautical Almanac.
1891.			h m s	h m s
Aug. 22	I. Ec. D.	Began to fade.	10 6 30	10 10 17
		Half gone.	10 8	
		Last seen.	10 10 58	
29	I. Ec. D.	Began to fade.	12 3 .	12 5 14
		Half gone.	12 4 30	
		Last seen.	12 5 45	

Date.		Satellite and Phenomena.		G.M.T. of Observation.	Time by Nautical Almanac.
1891.				h m s	h m s
Sept.	6	I. Tr. I.	Outer contact.	11 9	11 9
			Bisection.	11 11 30	
			Inner contact.	11 13 30	
	8	II. Tr. E.	Inner contact.	10 43	10 48
			Bisection.	10 45 30	
			Outer contact.	10 47	
		II. Sh. E.	Inner contact.	10 55	10 58
	10	III. Tr. E.	Half off.	10 49	10 51
			Just off.	10 52	
	28	IV. Ec. R.	First seen.	11 47 1	11 48 19
	29	I. Tr. I.	Outer contact.	10 47	10 47
			Inner contact.	10 50	
		I. Sh. I.	Just within disc.	11 26	11 23
	30	I. Ec. R.	First seen.	10 58	10 57·57
			Full.	11 3	
Oct.	7	I. Oc. D.	First contact.	9 50	9 50
			Half gone.	9 52	
			Just gone.	9 54	
		I. Ec. R.	First seen.	12 53 43	12 53 23
	9	I. Ec. R.	First seen.	7 22 27	7 22 12
	10	II. Tr. I.	First contact.	6 14	6 17
			Half on.	6 16	
			Just within.	6 18	
	12	III. Oc. D.	First contact.	10 28	10 30
			Bisection.	10 31	
			Just gone.	10 34	
	15	I. Tr. I.	First contact.	8 46 30	8 46
			Bisection.	8 48	
			Just within.	8 50	
	16	I. Ec. R.	First seen.	9 17 53	9 17 43
			Full.	9 22	
	19	II. Ec. R.	First seen.	7 37 59	7 37 49
			Full.	7 42	
	23	IV. Tr. E.	Half off.	6 48	7 7
			Outer contact.	6 50	
		III. Tr. E.	Half off.	7 10	7 16
			Outer contact.	7 18	

Date.		Satellite and Phenomena.		G.M.T. of Observation.	Time by Nautical Almanac.
1891.				h m s	h m s
		I. Oc. D.	Outer contact.	7 50	7 53
			Just gone.	7 55	
		I. Ec. R.	First seen.	11 13 47	11 13 17
			Full.	11 18	
Oct.	24	I. Sh. I.	Just within.	6 9	6 6
		I. Tr. E.	Half off.	7 17	7 20
			Outer contact.	7 20	
		I. Sh. E.	Inner contact.	8 20	8 24
			Half off.	8 24	
	30	III. Tr. I.	First contact.	7 28	7 27
			Bisection.	7 31	
			Inner contact.	7 35	
Nov.	2	II. Oc. D.	First contact.	7 36	7 39
			Bisection.	7 38	
			Just gone.	7 40	
	17	III. Oc. R.	Outer contact.	8 22	8 21
	20	II. Ec. R.	First seen.	7 24 12	7 23 26
			Full.	7 29	
Dec.	2	I. Tr. E.	Outer contact.	5 43	5 39
	4	II. Oc. D.	Contact.	7 7	7 7
			Just gone.	7 10	
	6	II. Sh. I.	Inner contact.	5 5	5 2
		II. Tr. E.	Outer contact.	5 12	5 10
	16	III. Ec. R.	First seen.	5 37 17	5 36 44
			Full.	5 40	
	17	I. Ec. R.	First seen.	8 8 12	8 9 26
	22	II. Ec. R.	First seen.	7 13 7	7 12 51
			Full.	7 17	
	29	II. Oc. D.	Contact.	4 31	4 34
			Last seen.	4 34	

Notes.

August 22.—Planet low. Much motion.

September 6.—Definition poor. Too much motion for any useful observation of the transit of the shadow.

September 8.—Cloudy. Poor definition. Impossible to see when the shadow was just off the disc.

September 10.—Planet too low for the first two observations given in the N.A. Definition bad. The shadow of III was a very striking object during its transit.

September 28.—Furious wind. Often cloudy.

September 29.—Bad night. Cloudy and windy. Clear now and then.
September 30.—Fair definition.
October 6.—Very bad sky.
October 7.—Very good definition, but seldom clear.
October 10.—Fair sky.
October 12.—Pretty good definition.
October 15.—Furious wind. Very bad definition. The sky cleared suddenly at 8.30 P.M.
October 16.—Poor definition.
October 19.—Much motion.
October 23.—Fair definition.
October 24.—Bad sky.
October 30.—Calm. Very misty. Steady images.
November 2.—Good definition.
November 17.—Violent motion.
November 20.—Good sky.
December 2.—Bad definition. Power 150. Definition not good enough for observing the shadow.
December 4.—Much motion.
December 6.—Much motion.
December 16.—Violent motion.
December 17.—Misty.
December 22.—Misty.
December 29.—Stormy.

Dark Transits of Jupiter's Satellites &c.

1891 September 29.—I began its transit about $10^h\ 48^m$. It soon faded away and was invisible at $11^h\ 15^m$; also at $11^h\ 40^m$.

1891 October 6.—Sky began to clear at 10.30 p.m.

IV was near the limb at 11^h and quite grey. It was in outer contact probably about $11^h\ 30^m$. Very bad sky.

At $11^h\ 30^m$ I was near the limb and much fainter than it was at 11^h.

1891 October 7.—I was quite bright up to its disappearance.

1891 October 10.—II did not appear to lose brightness as it approached the limb of *Jupiter*. When just on the disc it was a bright object. Was invisible at $6^h\ 40^m$, $7^h\ 15^m$, and $7^h\ 30^m$.

1891 October 12.—III did not appear to lose brightness as it approached the planet.

1891 October 15.—I is not as bright as the limb of the planet. IV and II appear much less bright than III.

1891 October 23.—$5^h\ 30^m$ *Jupiter* low; misty. IV in transit, and as dark as a shadow. III is also in transit; is smaller and not so dark as IV. The former is projected against a southern grey band; the latter is in a southern bright zone.

III was central about $5^h\ 30^m$.

$6^h\ 30^m$, both satellites dark as above, IV being not far from the limb.

$6^h\ 45^m$, IV invisible. III is dark yet.

$6^h\ 48^m$, IV half off and as bright as the limb of the planet.

$6^h\ 50^m$, III faint. At $7^h\ 5^m$ IV looked dim and strikingly less bright than I, which was approaching the disc. III invisible. At $7^h\ 10^m$ III was half off and quite as bright as the limb. When III and IV got away from the limb into the dark sky, their difference in size and brightness was very striking. The two were near together.

1891 November 17.—$8^h\ 30^m$, IV is strikingly faint, although it is not far (about $\frac{1}{4}$ of the diameter of *Jupiter*) from the limb.

1891 December 2.—I will come off the disc at $5^h\ 39^m$. It is now (5 P.M.) invisible, but the shadow is well seen. The satellite was not seen till nearly in inner contact, when it was about as bright as the limb of the planet, and it was very faint after it passed off the disc.

1891 December 4.—II was near the planet at 7^h, and grew faint as it approached the limb.

1891 December 5.—III dark during transit. At 5^h dark but not black. So also at $5^h\ 30^m$. Invisible at 6^h. Egress at $6^h\ 21^m$ not seen owing to wind and cloud.

1891 December 6.—II in transit. Invisible at $4^h\ 50^m$ and at 5^h.

1891 December 16.—I in transit. At 8^h invisible. At 9^h seen as a grey spot.

1891 December 92.—II became very faint as it approached the planet at $4^h\ 20^m$ and $4^h\ 30^m$.

IV began its transit at $2^h\ 36^m$. At 4^h and $4^h\ 30^m$ and 5^h it was a dark grey, large, diffuse spot and not circular. It was not visible at $6^h\ 15^m$, nor at $6^h\ 30^m$. Clouds prevented further observation.

Phenomena of Saturn's Satellites.

The weather in January and February was very bad, and no observations could be obtained.

1891 March 12.—Fair definition. Watched *Enceladus* near east end of ring. At east elongation at 10^h.

Tethys pn. Just under western end of ring. Not up at $9^h\ 15^m$; past at $9^h\ 20^m$.

Enceladus ps. Very difficult owing to cloud. Up between $10^h\ 20^m$ and $10^h\ 28^m$; past at $10^h\ 30^m$.

1891 April 16.—Bad sky. *Rhea* w. Up between $8^h\ 50^m$ and $9^h\ 5^m$; thought to be in line at 9^h.

Tethys w. Not up at $11^h\ 40^m$; past at $11^h\ 52^m$. Up between $11^h\ 45^m$ and $11^h\ 50^m$.

1891 April 17.—*Tethys* e. Misty. Satellite seen occasionally; judged in line between $10^h\ 10^m$ and $10^h\ 20^m$.

Enceladus very difficult owing to mist in air. Judged in line at $11^h\ 55^m$.

1891 April 22.—*Tethys* ps. In line with end of ring between $11^h\ 20^m$ and $11^h\ 30^m$.

1891 May 4.—*Rhea* w. Saw satellite occasionally. Nearly up at $10^h\ 25^m$.

1891 April 23.—*Tethys* fn. Up at $10^h\ 15^m$.

Observations of Occultations of Faint Stars during the Total Eclipse of the Moon on 1891 November 15, made at the Royal Observatory, Cape of Good Hope.

(*Communicated by David Gill, LL.D., F.R.S., H.M. Astronomer at the Cape of Good Hope.*)

In compliance with the request of Professor Döllen, conveyed by letter, preparations were made for observing the occultations of faint stars by the Moon during its total eclipse on November 15. Professor Döllen's circular, which accompanied his letter, gave the predicted Greenwich mean times of eleven disappearances and eight reappearances which might be observed at the Cape, together with the data for checking the accuracy of the predicted phenomena. These predictions, which had been obtained by a graphical process, were recomputed and found to be correct. The largest available instrument at this Observatory—the 10-inch guiding telescope of the photographic equatoreal—was used by Dr. Gill. The eye end of this instrument is fitted, not with the usual position micrometer, but with an eye-piece mounted on two slides at right angles to each other, by one of which the eye-piece can be displaced from the axis nearly 1° + or − in declination, and by the other to the same amount east or west of the axis. The amount of displacement is read off by finely divided scales. It was thus necessary to provide means for keeping the centre of the Moon coincident with the axis of the telescope, so that the centre of the eye-piece could be set by means of the scales (the proper readings having been previously computed) to the precise point of disappearance, and specially of reappearance of the star at the Moon's limb.

For this purpose an eye-piece of 2 inches focal length was adapted to the cover of the dark slide of the photographic telescope. The field of this eye-piece was about 34 inches in diameter, so that Mr. Woods found no difficulty, with the aid of the slow motions in R.A. and Decl., in keeping the Moon's centre in coincidence with the axis of the telescope during

the whole period of totality, and thus the phenomena were observed in every case precisely at the expected point.

The sidereal clock of the photographic observatory has a very feeble beat, and as the contingency of a high wind had to be faced (and, in fact, was blowing during the eclipse), the phenomena were observed not by the beat of this clock, but by the beat of a galvanic 'sounder,' actuated by the same relay as that which actuates the chronograph of the transit circle. Half an hour before totality the sidereal clock in the photographic observatory was set to exact coincidence with the beat of the sounder (the sixtieth second being identified by a missing beat), so that the observer had no difficulty in 'picking up the second' from the clock face at any moment. For further certainty the observer repeated aloud the seconds of his count, which was thus controlled by Mr. Power, who acted as clerk, and who recorded the times of observed phenomena dictated by the observer, and immediately afterwards indicated the settings of the scales for the next star. This method of observation left nothing to be desired. All possible errors of comparing clocks were entirely avoided, and the loud sharp beats of the sounder gave a certainty and precision to the observations which one must experience in order to realise. I am convinced that phenomena like occultations can be more accurately observed in this way than by chronographs, as (in the case of reappearances particularly, and specially in those of very faint stars) one sees at the expected point 'something' of which one notes the instant mentally; but it is necessary to wait a sensible time before one is *sure* that the desired phenomenon was observed. This is more particularly the case when (as on November 15) the definition is very bad—the Moon's limb undulating greatly, and the true phenomena of reappearance take place always within the apparent border of the limb. On account of the very unfavourable quality of the definition the lowest power, 120 diameters, had to be employed.

Mr. Finlay observed with the 7-inch Merz equatoreal, which is fitted with a position circle and filar micrometer by Repsold. The position circle and the wires are illuminated by light from a single fixed incandescent electric lamp, so that successive position angles can be pointed with great rapidity. Mr. Finlay has used this instrument for a very long series of observations of comets and occultations, and preferred to adopt his usual habit of employing the beats of a chronometer, which is compared before and after observation with the Transit clock. The lowest power, 120, was used on account of the bad state of the atmospheric conditions.

Mr. Finlay's observations were recorded by Mr. Cochrane.

Mr. Pett observed with the 6-inch Grubb equatoreal, which was fitted with a micrometer by Troughton and Simms, having bars instead of spider lines, which enable the position-angle on the Moon's limb to be accurately pointed without artificial illumination. The micrometer is provided with only two eye-pieces,

one magnifying 90, the other 230 diameters. Of these Mr. Pett preferred to use the higher power, with which, however, the star images were very diffused, especially so during the latter half of totality.

Mr. Pett's observations were recorded by Mr. Woodgate.

Mr. Cox observed with the heliometer. There are four intersecting metal bars forming a square in the field of view; the centre of this square marks the optical axis. Two sides of the square are parallel to the motion of the slides. One of the other wires (at right angles to the motion of the slide) was used to cut off the required segment of the Moon's limb. This wire is identified by its parallelism to a micrometer screw in the eye-piece, which has special functions that need not here be referred to. By simply setting the position-circle of the heliometer to the required position-angle, the observer was enabled to find with certainty the required point of the Moon's limb. The optical centres of the segments of the object-glass were very carefully adjusted to exact coincidence, so that the instrument was practically used as an ordinary telescope of 7½ inches aperture, with the exception that the telescope itself was revolved about its axis instead of the micrometer only being so. Mr. Cox employed an eye-piece magnifying 155 diameters; his observations were recorded by the beats of a sounder, the same being actuated by the Transit clock relay in the same manner as in Dr. Gill's observations, Mr. Goodman acting as clerk.

The relative positions of the various telescopes to the Transit circle and the heights of the object-glasses above sea-level at mean epoch of the eclipse are—

	From Transit Circle.		Height above sea-level.
Photographic Equatoreal	450 feet S.	130 feet E.	57 feet
7-inch Equatoreal	200 „ N.	145 „ W.	45 „
6 „ „	370 „ S.	50 „ E.	59 „
Heliometer	200 „ N.	60 „ E.	55 „

The following Table gives the sidereal times of the various phenomena as determined by the different observers:—

Star's No.	Mag.	Phenomenon.	Gill.	Finlay.	Pett.	Cox.
			h m s	h m s	h m s	h m s
(42) Probably		D	4 23 46·3 (South of * No. 40.)	...	...	...
40	10–11		4 27 37·4	4 27 39·4 Not certain.	4 27 37·9 Sharp disappearance.	4 27 37·3
25	9·5	R	4 35 17·3 Bad observation.	Star not seen.	Not seen till clear of limb.	Not seen till too late.
38	10–11	D	...	...	...	...
46	9·5	D	...	Star not seen.	...	...
31	9·0	R	4 40 23·8 Very good; star within limb.	4 40 35·2 Very good; star within moon's limb when first seen. [Note probably miscounted 10 secs. D.G.]	4 40 23·3	...
51	11	D	Lost before reaching limb.	Cloud passing at time.	Lost sight of when nearing limb.	Too faint.
50	11	D	4 57 9·0	Cloud passing at time.	Lost sight of near limb.	Too faint.
34	10–11	R	5 8 19±	5 8 16·6	...	...
58	11	D	Too faint.	Star not seen.	...	Too faint.

Star's No.	Mag.	Phenomenon.	Gill.	Finlay.	Pett.	Cox.
			h m s	h m s	h m s	h m s
54	9·2	D	5 11 35·2 Def. bad; limb boiling.	5 11 36·6 Good.	5 11 35·9	5 11 35·2 Good.
60	9·5	D	5 18 11 A guess.	...	Lost sight of near limb.	...
38	10–11	R	5 21 15·2 Very good.	5 21 21·9 Good.	...	5 21 15·2 Good.
40	10–11	R	5 27 56·7	5 27 58·0 Very faint.	...	...
65	9·5	D	Star not seen.	Star not seen.	No star seen within five minutes of time.	Star not seen.
42	10–11	R	5 38 58·4	5 39 7·2 Good.	Not seen till clear of limb.	5 39 0·8 Very rough.
46	9·5	R	5 52 24·2	5 52 20·9 Faint; slightly within limb when seen.	Not seen till clear of limb.	5 52 25·2
51	11	R	...	...	...	...
76	8	D	Star lost near limb.	Could not follow to limb.	Moon's limb too bright.	Limb boiling too much.
98	1	D	...	...	...	...

Observations of the Total Eclipse of the Moon, 1891, *November* 15, *made at Edinburgh.* By Ralph Copeland, Ph.D.

At the Royal Observatory, Calton Hill, the sole result that could be secured was the immersion of the 11 mag. star No. 59 of Dr. Döllen's list, which disappeared suddenly at $11^h\ 44^m\ 13^s{\cdot}2$, Greenwich mean time. Observer, Mr. Thomas Heath, with the 24-inch reflector and a power of 138.

At Blackford Hill, on the site of the new observatory, I followed the eclipse with an achromatic eye-piece, magnifying sixty-four times on the 12-inch Browning reflector. During the whole of the eclipse the clouds were very troublesome, but most of all during the total phase; hence not a single one out of twenty-one predicted occultation phenomena was visible. The beginning of the eclipse was also completely hidden; but about a quarter of an hour later the clouds broke somewhat, so that a number of ingresses of craters were recorded, as were also the beginning and end of totality, together with a few egresses of lunar features. With the power used the shading of the margin of the shadow deepened quite gradually, until within about the width of *Tycho* (40″) of the full shadow; thence it rapidly increased in density. The inner (darker) border of this inner shading was considered as marking the edge of the true shadow.

Greenwich Mean Time. h	m	s	
10	53	0	Plato, ingress of 1st edge.
10	54	0	Plato, ingress of 2nd edge.
11	3	57	Manilius, ingress of 1st edge.
11	4	23	Manilius, ingress of 2nd edge.
11	7	8	Menelaus, ingress of centre.
11	10	9	Plinius, ingress of centre.
11	12	33	Tycho, ingress of 1st edge.
11	36	17	The shadow had apparently reached the Moon's limb; the disc, however, seemed suddenly to light up again as if the total phase had not actually commenced.
11	37	47	Moon certainly completely within the shadow.
13	0	0	Clear for a short time. Moon of a beautiful orange-copper colour. All the chief markings distinctly visible.
13	0	56	End of total phase.
13	2	44	Grimaldi, egress of 1st edge.
13	3	29	Grimaldi, egress of 2nd edge.
13	13	0	Moon clear for a moment. The markings within the shadow almost altogether invisible. Shadow of a steel-grey tint.
13	18	16	Tycho, egress of 1st edge.
13	20	12	Tycho, egress of 2nd edge.
13	23	21	Copernicus, egress of centre.
13	23	58	Copernicus, egress of 2nd edge.

All the later phenomena were hidden by the clouds, which, however, cleared off for a few hours just after the end of the eclipse.

Observations of Occultations of Stars by the Moon and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the year 1891.

(Communicated by the Astronomer Royal.)

Occultations of Stars by the Moon.

Day.		Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
1891	Jan. 4	Reapp. 2 Libræ	Altaz.	[illegible]	Dark	[illegible]	[illegible]
	Feb. 12 (a)	Disapp. 33 Ceti	"	[illegible]	"	[illegible]	[illegible]
	17	" 121 Tauri	Corbett Equat.	[illegible]	"	[illegible]	[illegible]
	Mar. 2 (b)	Reapp. B A C 5395	Altaz.	[illegible]	"	[illegible]	[illegible]
	26	" l^2 Virginis	"	[illegible]	"	[illegible]	[illegible]
	28	" ν^1 Libræ	"	[illegible]	"	[illegible]	[illegible]
	Apr. 18	Disapp. 42 Leonis	E. Equat.	[illegible]	"	[illegible]	[illegible]
	18 (c)	" 42 Leonis	Altaz.	[illegible]	"	[illegible]	[illegible]
	20	Reapp. ν Virginis	E. Equat.	55	"	[illegible]	[illegible]
	Aug. 14	Disapp. 26 Ophiuchi	Altaz.	[illegible]	"	[illegible]	[illegible]
	Sept. 22 (d)	Reapp. 53 Tauri	"	[illegible]	"	[illegible]	[illegible]
	Oct. 15	Disapp. 30 Piscium	"	[illegible]	"	[illegible]	[illegible]

Notes.

(a) Not a good observation; the star frequently disappeared behind clouds previous to final disappearance.
(b) Star very faint; moon low. (c) Star very faint.
(d) This observation may possibly be late. At $10^h 59^m 45^s$ it was thought that a star was seen for a moment.

Phenomena of Jupiter's Satellites.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1891 June 16 (a)	III.	Tr. Ing. First contact	Altaz.	100	13 28 50	13 29	W. R.
16	III.	Last seen	"	"	13 38 4		"
July 6	II.	Tr. Egr. First seen	E. Equat.	150	13 43 54		H.
6	II.	Bisection	"	"	13 45 48	13 45	"
6	II.	Last contact	"	"	13 49 33		"
6	I.	Tr. Ing. First contact	"	"	13 44 24		"
6	I.	Bisection	"	"	13 46 58	13 48	"
6	I.	Last seen	"	"	13 49 41		"
13	II.	Tr. Ing. First contact	"	"	13 21 11		A. C.
13	II.	Bisection	"	"	13 22 23	13 21	"
13	II.	Last seen	"	"	13 24 33		"
22 (b)	III.	Tr. Egr. Bisection	Altaz.	100	11 25 4	11 25	H. T.
22	III.	Last contact	"	"	11 27 54		"
22 (c)	II.	Occ. R. First seen	E. Equat.	150	13 18 49		"
22	II.	Bisection	"	"	13 20 49	13 21	"
22	II.	Last contact	"	"	13 22 34		"
29	II.	Ecl. D. Last seen	Altaz.	100	11 4 48	11 5 23	H. F.
Aug. 6	I.	Ecl. D. Last seen	E. Equat.	150	11 52 32	11 52 2	A. M.
14	I.	Tr. Ing. First contact	"	"	11 30 50	11 33	C. D.
14	I.	Last seen	"	"	11 34 49		"

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1891 Aug. 14	II.	Tr. Ing. First contact	E. Equat.	150	11 56 50		C. D.
14	II.	Bisection	,,	,,	11 58 25	11 58	,,
14	II.	Last seen	,,	,,	12 2 9		,,
15	I.	Occ. R. First seen	,,	,,	11 2 37		H.
15	I.	Bisection	,,	,,	11 4 14	11 4	,,
15	I.	Last contact	,,	,,	11 6 24		,,
30	II.	Ecl. D. Last seen	,,	,,	10 43 9	10 42 4	L.
30 (*d*)	I.	Tr. Egr. First seen	,,	,,	11 37 5	11 44	,,
30	I.	Last contact	,,	,,	11 43 29		,,
Sept. 10	III.	Tr. Ing. First contact	Altaz.	100	7 29 34	7 31	T.
10	III.	Last seen	,,	,,	7 36 18		,,
10	III.	Tr. Egr. Bisection	E. Equat.	220	10 47 28	10 51	H.
10	III.	Last contact	,,	,,	10 53 2		,,
15 (*e*)	I.	Tr. Ing. First contact	Altaz.	100	7 17 31	7 18	L.
15	I.	Tr. Egr. First seen	,,	,,	9 32 59	9 36	,,
15	I.	Last contact	,,	,,	9 37 33		,,
15	II.	Tr. Ing. First contact	,,	,,	10 5 44		,,
15	II.	Bisection	,,	,,	10 8 33		,,
15	II.	Last seen	,,	,,	10 12 3	10 13	,,
15	II.	First contact	E. Equat.	220	10 9 58		A. C.
15	II.	Bisection	,,	,,	10 11 44		,,
15	II.	Last seen	,,	,,	10 13 31		,,

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1891 Sept. 22	I.	Tr. Ing. First contact	Altaz.	100	8 58 34		H.
22	I.	Bisection	„	„	9 0 13	9 2	„
22	I.	Last seen	„	„	9 2 53		„
22	I.	Tr. Egr. First seen	E. Equat.	220	11 16 12		T.
22	I.	Last contact	„	„	11 19 27		„
22	I.	First seen	Altaz.	100	11 16 46	11 20	H.
22	I.	Bisection	„	„	11 19 21		„
22	I.	Last contact	„	„	11 22 30		„
23	I.	Ecl. R. First seen	„	„	9 3 51		L.
23	I.	First seen	E. Equat.	220	9 3 21	9 2 37	A. C.
23 (*f*)	I.	Full brightness	„	„	9 4 41		„
28	IV.	Ecl. D. Last seen	„	150	7 59 36	8 6 53	H.
28	III.	Ecl. R. First seen	„	„	9 17 24	9 20 7	„
28	III.	Full brightness	„	„	9 18 45		„
28 (*g*)	IV.	Ecl. R. First seen	„	„	11 45 56	11 48 19	„
28	IV.	Full brightness	„	„	11 55 0		„
28	I.	Occ. D. First contact	Altaz.	100	13 33 52	13 38	C. M.
28	I.	Last seen	„	„	13 36 26		„
Oct. 9	I.	Ecl. R. First seen	E. Equat.	150	7 22 24	7 22 12	A. C.
9	I.	Full brightness	„	„	7 24 29		„

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1891 Oct. 12	III.	Occ. D. First contact	E. Equat.	220	10 26 47		H.
12	III.	Bisection	"	"	10 30 2		"
12	III.	Last seen	"	"	10 34 11	10 30	"
12	III.	First contact	Altaz.	100	10 27 45		H. F.
12	III.	Bisection	"	"	10 29 40		"
12	III.	Last seen	"	"	10 32 4		"
14 (*h*)	I.	Occ. D. Last seen	"	"	11 37 59	11 38	H.
15 (*k*)	IV.	Ecl. R. First seen	"	"	5 59 13	5 58 52	A. C.
15	IV.	Full brightness	"	"	6 4 43		"
15	I.	Tr. Ing. First contact	E. Equat.	55	8 45 57		"
15	I.	Bisection	"	"	8 46 52	8 46	"
15	I.	Last seen	"	"	8 49 9		"
15	I.	Tr. Egr. First seen	"	"	11 4 35		"
15	I.	Bisection	"	"	11 5 42	11 4	"
15	I.	Last contact	"	"	11 7 46		"
16 (*l*)	I.	Ecl. R. First seen	"	"	9 17 51	9 17 43	L.
16	I.	Full brightness	"	"	9 21 18		"
17	II.	Tr. Ing. First contact	"	220	8 36 58	8 39	T.
17	II.	Last seen	"	"	8 41 27		"
17	II.	Tr. Egr. First seen	"	"	11 29 56	11 32	"
17	II.	Last contact	"	"	11 34 10		"
23 (*m*)	IV.	Tr. Egr. Last contact	"	55	7 9 2	7 7	C. D.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of N.A. h m s	Observer.
1891 Oct. 23	I.	Occ. D. First contact	E. Equat.	220	7 51 1		C. D.
23	I.	Bisection	,,	,,	7 52 27	7 53	,,
23	I.	Last seen	,,	,,	7 54 15		,,
Nov. 2 (a)	II.	Occ. D. First contact	,,	220	7 30 11		L.
2	II.	Bisection	,,	,,	7 34 17	7 39	,,
2	II.	Last seen	,,	,,	7 39 9		,,
7	I.	Tr. Ing. First contact	,,	,,	8 39 23		H.
7	I.	Bisection	,,	,,	8 42 8	8 42	,,
7	I.	Last seen	,,	,,	8 45 57		,,
7	I.	Tr. Egr. First seen	,,	,,	10 58 25		,,
7	I.	Bisection	,,	,,	11 0 35	11 1	,,
7	I.	Last contact	,,	,,	11 3 0		,,
8	I.	Occ. D. First contact	,,	,,	5 58 47		A. C.
8	I.	Bisection	,,	,,	6 0 11	6 2	,,
8	I.	Last seen	,,	,,	6 2 8		,,
11	II.	Tr. Egr. First seen	,,	,,	8 5 24	8 8	H.
11	II.	Bisection	,,	,,	8 8 9		,,
Dec. 2	I.	Tr. Egr. Last contact	,,	,,	5 42 40		L.
2	I.	First seen	Altaz.	100	5 37 58	5 39	A. C.
2	I.	Last contact	,,	,,	5 43 55		,,
4	II.	Occ. D. First contact	E. Equat.	150	7 2 44		,,
4	II.	Bisection	,,	,,	7 3 54	7 7	,,
4	II.	Last seen	,,	,,	7 6 56		,,

Day.	Satellite.	Phenomenon.	Telescope.	wer.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
					h m s	h m s	
1891 Dec. 5 (o)	III.	Tr. Egr. First seen	E. Equat.	220	6 18 2		H.
5	III.	Bisection	,,	,,	6 20 47		,,
5	III.	Last contact	,,	,,	6 25 46	6 21	,,
5 (p)	III.	Bisection	Photo. Equat.	225	6 19 38		C. D.
5	III.	Last contact	,,	,,	6 21 58		,,
9	I.	Tr. Ing. First contact	E. Equat.	150	5 15 22	5 17	H.
9	I.	Last seen	,,	,,	5 19 47		,,
17	I.	Ecl. R. First seen	Altaz.	100	8 9 59	8 9 26	H.
17	I.	Full brightness	,,	,,	8 11 54		,,

Notes.

(*a*) Satellite very faint. (*b*) The phenomenon occurred so much earlier than was expected that the first contact was lost. *Jupiter* was examined at about $11^h\ 18^m$, and a point of light was suspected at the place where III. was ultimately seen, but the appearance was intermittent, and very like scintillations at other points of the limb. The attention of the observer was then called away till $11^h\ 25^m$.

(*c*) Cloudy at times, but quite clear at first and last contacts. (*d*) A good observation. Limb very steady and well defined.

(*e*) A rough observation; *Jupiter* clouded. Last contact not seen; cloudy. (*f*) Rather uncertain.

(*g*) The satellite reappeared almost coincident with III.; the time may be late on this account.

(*h*) *Jupiter* in light cloud; satellite hardly visible; observation not considered good. (*k*) Near I.; the time may be late on this account.

(*l*) A very good observation. (*m*) Satellite very faint indeed; observation not worth much.

(*n*) Observation not good; cloudy. The bisection probably the best observation, as *Jupiter* was bright for some 30^s about that time.

(*o*) Not a good observation; windy; definition bad. (*p*) Very unsteady; windy.

The aperture of the object glass of the East Equatoreal is 6·7 inches, of the Corbett 6·5 inches, and of the Altaz. $3\frac{3}{4}$ inches. The abbreviation "Photo. Equat." denotes the guiding telescope of the Photographic Equatoreal, aperture 10 inches.

The initials H. T., T., L., H., A. C., J. P., W. R., H. F., A. M., C. M., C. D., are those of Mr. Turner, Mr. Thackeray, Mr. Lewis, Mr. Hollis, Mr. Crommelin, Mr. Power, Mr. Russell, Mr. Furner, Mr. Miskin, Mr. Martin, and Mr. Davidson respectively.

Ephemeris of Juno near the time of Opposition, 1891; *computed from the Corrected Elements published in "Monthly Notices," vol. l., p.* 495.

(*Communicated by the Superintendent of the "Nautical Almanac."*)

At Transit at Greenwich.

Month and Day.	Apparent Right Ascension.	Apparent Declination.	Month and Day.	Apparent Right Ascension.	Apparent Declination.
	h m s	° ′ ″		h m s	° ′ ″
July 23	21 55 1·85	S. 1 10 23·9	Aug. 22	21 33 31·06	S. 4 50 15·5
24	21 54 31·26	1 14 46·5	23	21 32 42·66	4 59 59·7
25	21 53 59·44	1 19 22·7	24	21 31 54·54	5 9 48·8
26	21 53 26·43	1 24 12·5	25	21 31 6·76	5 19 42·3
27	21 52 52·25	1 29 15·8	26	21 30 19·40	5 29 39·8
28	21 52 16·94	1 34 32·7	27	21 29 32·51	5 39 40·7
29	21 51 40·51	1 40 3·0	28	21 28 46·16	5 49 44·6
30	21 51 2·99	1 45 46·6	29	21 28 0·41	5 59 50·8
31	21 50 24·43	1 51 43·6	30	21 27 15·32	6 9 58·9
Aug. 1	21 49 44·86	1 57 53·7	31	21 26 30·97	6 20 8·2
2	21 49 4·34	2 4 16·7	Sept. 1	21 25 47·41	6 30 18·2
3	21 48 22·91	2 10 52·5	2	21 25 4·70	6 40 28·5
4	21 47 40·59	2 17 41·0	3	21 24 22·90	6 50 38·6
5	21 46 57·45	2 24 41·9	4	21 23 42·10	7 0 47·7
6	21 46 13·54	2 31 54·7	5	21 23 2·31	7 10 55·5
7	21 45 28·90	2 39 19·5	6	21 22 23·60	7 21 1·3
8	21 44 43·59	2 46 55·8	7	21 21 46·03	7 31 4·8
9	21 43 57·66	2 54 43·3	8	21 21 9·66	7 41 5·5
10	21 43 11·18	3 2 41·8	9	21 20 34·51	7 51 2·9
11	21 42 24·19	3 10 50·9	10	21 20 0·65	8 0 56·5
12	21 41 36·76	3 19 10·2	11	21 19 28·11	8 10 45·8
13	21 40 48·94	3 27 39·3	12	21 18 56·94	8 20 30·5
14	21 40 0·79	3 36 17·9	13	21 18 27·17	8 30 10·2
15	21 39 12·37	3 45 5·4	14	21 17 58·83	8 39 44·3
16	21 38 23·75	3 54 1·6	15	21 17 31·97	8 49 12·6
17	21 37 34·99	4 3 6·1	16	21 17 6·62	8 58 34·8
18	21 36 46·15	4 12 18·3	17	21 16 42·80	9 7 50·5
19	21 35 57·26	4 21 37·8	18	21 16 20·53	9 16 59·4
20	21 35 8·42	4 31 4·2	19	21 15 59·85	9 26 1·1
21	21 34 19·66	S. 4 40 36·9	20	21 15 40·76	S. 9 34 55·4

Month and Day.	Apparent Right Ascension. h m s	Apparent Declination. ° ′ ″	Month and Day.	Apparent Right Ascension. h m s	Apparent Declination. ° ′ ″
Sept. 21	21 15 23·30	S. 9 43 42·0	Oct. 20	21 19 32·05	S. 12 47 38·8
22	21 15 7·48	9 52 20·7	21	21 20 6·31	12 51 17·7
23	21 14 53·34	10 0 51·1	22	21 20 42·16	12 54 45·6
24	21 14 40·88	10 9 13·0	23	21 21 19·58	12 58 2·5
25	21 14 30·12	10 17 26·1	24	21 21 58·57	13 1 8·4
26	21 14 21·08	10 25 30·2	25	21 22 39·10	13 4 3·3
27	21 14 13·78	10 33 25·1	26	21 23 21·16	13 6 47·2
28	21 14 8·24	10 41 10·5	27	21 24 4·74	13 9 20·1
29	21 14 4·45	10 48 46·2	28	21 24 49·82	13 11 42·1
30	21 14 2·43	10 56 12·1	29	21 25 36·39	13 13 53·1
Oct. 1	21 14 2·18	11 3 28·0	30	21 26 24·42	13 15 53·2
2	21 14 3·73	11 10 33·8	31	21 27 13·90	13 17 42·4
3	21 14 7·05	11 17 29·4	Nov. 1	21 28 4·81	13 19 20·9
4	21 14 12·17	11 24 14·4	2	21 28 57·13	13 20 48·4
5	21 14 19·08	11 30 49·0	3	21 29 50·84	13 22 5·4
6	21 14 27·76	11 37 13·0	4	21 30 45·92	13 23 11·5
7	21 14 38·24	11 43 26·1	5	21 31 42·35	13 24 7·2
8	21 14 50·49	11 49 28·6	6	21 32 40·12	13 24 52·2
9	21 15 4·50	11 55 20·1	7	21 33 39·19	13 25 26·9
10	21 15 20·28	12 1 0·6	8	21 34 39·56	13 25 51·2
11	21 15 37·81	12 6 30·1	9	21 35 41·18	13 26 5·0
12	21 15 57·07	12 11 48·7	10	21 36 44·06	13 26 8·5
13	21 16 18·06	12 16 56·2	11	21 37 48·15	13 26 1·8
14	21 16 40·76	12 21 52·7	12	21 38 53·44	13 25 45·0
15	21 17 5·16	12 26 38·2	13	21 39 59·91	13 25 18·0
16	21 17 31·24	12 31 12·4	14	21 41 7·55	13 24 41·2
17	21 17 58·98	12 35 35·6	15	21 42 16·32	13 23 54·4
18	21 18 28·37	12 39 47·7	16	21 43 26·21	S. 13 22 57·7
19	21 18 59·40	S. 12 43 48·8			

"Nautical Almanac" Office,
3 *Verulam Buildings, Gray's Inn, W.C.:*
1892 *January* 8.

Ephemerides of the Satellites of Saturn, 1891–92. By A. Marth.

(*Continued.*)

The following are continuations of the Tables explained on pp. 566, ff. of vol. li.:—

Greenwich Noon.		P	L	Diff.	B	*B*	A–L	Long. of ♄'s Central Mer.
1892.		°	°		°	°	°	°
Mar.	2	355·832	179·086		+2·451	+1·926	−1·543	94·36
				131				
	4	·819	178·955		2·378	1·956	1·351	342·12
				133				
	6	·806	178·822		2·304	1·987	1·157	229·88
				135				
	8	·793	178·687		2·230	2·017	0·961	117·63
				137				
	10	·779	178·550		2·155	2·047	0·764	5·38
				137				
	12	355·766	178·413		+2·080	+2·078	−0·566	253·13
				138				
	14	·752	178·275		2·005	2·108	−0·367	140·87
				139				
	16	·739	178·136		1·930	2·139	−0·168	28·61
				139				
	18	·725	177·997		1·855	2·169	+0·032	276·35
				139				
	20	·711	177·858		1·781	2·199	+0·231	164·08
				139				
	22	355·698	177·719		+1·707	+2·230	+0·430	51·81
				138				
	24	·684	177·581		1·634	2·260	0·629	299·53
				137				
	26	·671	177·444		1·561	2·290	0·827	187·25
				135				
	28	·658	177·309		1·490	2·321	1·023	74·96
				134				
	30	·645	177·175		1·420	2·351	1·218	322·67
				133				
Apr.	1	355·632	177·042		+1·352	+2·381	+1·411	210·37
				130				
	3	·619	176·912		1·285	2·412	1·601	98·06
				127				
	5	·607	176·785		1·220	2·442	1·789	345·74
				125				
	7	·595	176·660		1·156	2·472	1·975	233·42
				122				
	9	·583	176·538		1·094	2·503	2·157	121·09
				118				
	11	355·571	176·420		+1·035	+2·533	+2·336	8·75
				115				
	13	·560	176·305		0·977	2·563	2·512	256·41
				112				
	15	·549	176·193		0·922	2·594	2·684	144·06
				108				
	17	·539	176·085		0·869	2·624	2·852	31·70
				103				
	19	·529	175·982		0·819	2·654	3·017	279·33
				99				
	21	355·520	175·883		+0·771	+2·684	+3·177	166·95
				95				
	23	·511	·788		0·726	2·715	3·332	54·57
				91				
	25	·502	·697		0·683	2·745	3·483	302·18
				85				
	27	·494	·612		0·643	2·775	3·629	189·78
				80				
	29	·486	·532		0·606	2·805	3·770	77·37
				75				

Greenwich Noon.		P	L	Diff.	B	*B*	A−L	Long. of ♄'s Central Mer.
1892.		°	°		°	°	°	°
May	1	355·479	175·457	70	+0·573	+2·836	+3·905	324·96
	3	·472	·387	65	0·542	2·866	4·036	212·54
	5	·466	·322	59	0·514	2·896	4·161	100·11
	7	·461	·263	53	0·490	2·926	4·280	347·67
	9	·456	·210	48	0·468	2·956	4·394	235·22
	11	355·451	175·162	42	+0·450	+2·986	+4·502	122·76
	13	·447	·120	36	0·435	3·017	4·604	10·30
	15	·444	·084	30	0·423	3·047	4·701	257·83
	17	·441	·054	24	0·414	3·077	4·792	145·35
	19	·439	·030	19	0·408	3·107	4·877	32·86
	21	355·437	175·011	12	+0·406	+3·137	+4·956	280·37
	23	·436	174·999	6	0·407	3·167	5·029	167·87
	25	·435	174·993	0	0·411	3·198	5·095	55·37
	27	·435	174·993	5	0·419	3·228	5·156	302·85
	29	·436	174·998	12	0·430	3·258	5·211	190·33
	31	355·437	175·010	18	+0·444	+3·288	+5·260	77·80
June	2	·439	·028	24	0·461	3·318	5·302	325·27
	4	·441	·052	30	0·482	3·348	5·338	212·73
	6	·444	·082	36	0·505	3·378	5·369	100·18
	8	·447	·118	41	0·542	3·408	5·394	347·62
	10	355·451	175·159	47	+0·562	+3·438	+5·413	235·06
	12	·456	·206	54	0·595	3·468	5·426	122·50
	14	·461	·260	59	0·631	3·498	5·433	9·93
	16	·467	·319	64	0·670	3·529	5·434	257·35
	18	·473	·383	70	0·712	3·559	5·430	144·77
	20	355·480	175·453	76	+0·757	+3·589	+5·420	32·18
	22	·487	·529	81	0·804	3·619	5·405	279·59
	24	·495	·610	87	0·854	3·649	5·384	166·99
	26	·503	·697	92	0·907	3·679	5·358	54·39
	28	·512	·789	97	0·963	9·709	5·326	301·79
	30	345·521	175·886	103	+1·022	+3·739	+5·289	189·18
July	2	·531	175·989	108	1·083	3·769	5·247	76·56
	4	·541	176·097	112	1·147	3·799	5·200	323·94
	6	·552	176·209	117	1·213	3·829	5·148	211·32
	8	·564	176·326	122	1·282	3·859	5·091	98·70
	10	355·576	176·448	127	+1·353	+3·889	+5·029	346·07
	12	·588	176·575	131	1·426	3·918	4·963	233·44
	14	·601	176·706	136	1·501	3·948	4·892	120·81

Greenwich Noon.	P	L	Diff.	B	*B*	A−L	Long. of ♄'s Central Mer.
1892.	°	°		°	°	°	°
July 16	·614	176·842	140	1·579	3·978	4·817	8·17
18	·627	176·982	145	1·659	4·008	4·737	255·53
20	355·641	177·127	148	+1·741	+4·038	+4·653	142·89
22	·656	177·275	153	1·825	4·068	4·565	30·25
24	·671	177·428	157	1·910	4·098	4·472	277·60
26	·686	177·585	160	1·998	4·128	4·376	164·95
28	·702	177·745	164	2·087	4·158	4·276	52·30
30	355·718	177·909	168	+2·178	+4·188	+4·172	299·65
Aug. 1	·734	178·077	171	2·271	4·218	4·065	187·00
3	·751	178·248	175	2·366	4·248	3·954	74·35
5	·768	178·423	178	2·462	4·277	3·840	321·70
7	·785	178·601	181	2·559	4·307	3·723	209·04
9	355·803	178·782		+2·658	+4·337	+3·602	96·39

The difference of successive values of the longitude of *Saturn's* central meridian (corrected for phase) in the last column varies between 1687°·77 and 1687°·34.

Greenwich Noon.	Semidiameter of Ball. Equat.	Phase.	Polar.	Semiaxis of Ring. Major.	Minor.	*Mimas.* a_1	b_1	l_1−L	Diff.
1892.	″	″	″	″	″	″	″	°	°
Mar. 2	9·56	0·003	8·63	22·05	0·94	30·13	+1·29	326·17	764·16
4	9·57	·003	8·64	22·07	0·92	30·16	1·25	10·33	·15
6	9·58	·002	8·64	22·09	0·89	30·18	1·21	54·48	·15
8	9·59	·002	8·65	22·11	0·86	30·20	1·17	98·63	·15
10	9·60	·001	8·66	22·12	0·83	30·22	1·14	142·78	·15
12	9·60	...	8·66	22·12	0·80	30·23	+1·10	186·93	·15
14	9·60	...	8·66	22·13	0·77	30·24	1·06	231·08	·15
16	9·60	...	8·66	22·13	0·74	30·24	1·02	275·23	·14
18	9·60	...	8·66	22·13	0·72	30·24	0·98	319·37	·14
20	9·60	..	8·66	22·13	0·69	30·23	0·94	3·51	·13
22	9·60	...	8·66	22·12	0·66	30·22	+0·90	47·64	764·14
24	9·59	...	8·65	22·11	0·63	30·21	0·86	91·78	·13
26	0·58	·001	8·65	22·09	0·60	30·19	0·82	135·91	·12
28	9·58	·001	8·64	22·08	0·57	30·17	0·78	180·03	·12
30	9·57	·002	8·63	22·06	0·55	30·14	0·75	224·15	·12
Apr. 1	9·56	·002	8·62	22·03	0·52	30·11	+0·71	268·27	·11
3	9·55	·004	8·61	22·01	0·49	30·07	0·67	312·38	·11
5	9·53	·005	8·60	21·98	0·47	30·03	0·64	356·49	·10
7	9·52	·006	8·59	21·95	0·44	29·99	0·60	40·59	·10

Greenwich Noon.	Semidiameter of Ball. Equat.	Phase.	Polar.	Semiaxis of Ring. Major.	Minor.	*Mimas.* a_1	b_1	$l_1 - L$	Diff.
1892.	″	″	″	″	″	″	″	°	°
Apr. 9	9·51	·007	8·57	21·91	0·42	29·94	0·57	84·69	·09
11	9·49	·008	8·56	21·87	0·40	29·89	+0·54	128·78	764·08
13	9·47	·009	8·54	21·83	0·37	29·84	0·51	172·86	·08
15	9·45	·010	8·53	21·79	0·35	29·78	0·48	216·94	·07
17	9·43	·012	8·51	21·75	0·33	29·72	0·45	261·01	·07
19	9·41	·013	8·49	21·70	0·31	29·65	0·42	305·08	·06
21	9·39	·014	8·47	21·65	0·29	29·58	+0·40	349·14	·06
23	9·37	·015	8·45	21·60	0·27	29·51	0·37	33·20	·05
25	9·34	·017	8·43	21·54	0·26	29·44	0·35	77·25	·04
27	9·32	·019	8·41	21·49	0·24	29·36	0·33	121·29	·03
29	9·29	·020	8·39	21·43	0·23	29·28	0·31	165·32	·03
May 1	9·27	·022	8·36	21·37	0·21	29·20	+0·29	209·35	764·02
3	9·24	·023	8·34	21·31	0·20	29·12	0·28	253·37	·01
5	9·22	·024	8·31	21·25	0·19	29·03	0·26	297·38	·00
7	9·19	·026	8·29	21·18	0·18	28·95	0·25	341·38	764·00
9	9·16	·027	8·26	21·12	0·17	28·86	0·24	25·38	763·99
11	9·13	·028	8·24	21·05	0·17	28·77	+0·23	69·37	·99
13	9·10	·029	8·21	20·99	0·16	28·68	0·22	113·36	·98
15	9·07	·031	8·19	20·92	0·15	28·59	0·21	157·34	·97
17	9·04	·032	8·16	20·85	0·15	28·49	0·21	201·31	·96
19	9·01	·033	8·13	20·78	0·15	28·40	0·20	245·27	·95
21	8·98	·034	8·10	20·71	0·15	28·30	+0·20	289·22	763·95
23	8·95	·034	8·08	20·64	0·15	28·20	0·20	333·17	·95
25	8·92	·035	8·05	20·57	0·15	28·11	0·20	17·12	·93
27	8·89	·036	8·02	20·50	0·15	28·01	0·20	61·05	·93
29	8·86	·037	7·99	20·43	0·15	27·91	0·21	104·98	·92
31	8·83	·037	7·96	20·36	0·16	27·81	+0·22	148·90	·92
June 2	8·80	·038	7·94	20·28	0·16	27·72	0·22	192·82	·91
4	8·77	·038	7·91	20·21	0·17	27·62	0·23	236·73	·90
6	8·74	·038	7·88	20·14	0·18	27·52	0·24	280·63	·90
8	8·71	·038	7·85	20·07	0·19	27·42	0·25	324·53	·89
10	8·68	0·039	7·83	20·00	0·20	27·33	+0·27	8·42	763·88
12	8·64	·039	7·80	19·93	0·21	27·23	0·28	52·30	·88
14	8·61	·039	7·77	19·86	0·22	27·14	0·30	96·18	·87
16	8·58	·039	7·74	19·79	0·23	27·04	0·32	140·05	·87
18	8·55	·038	7·72	19·72	0·24	26·95	0·34	183·92	·86
20	8·52	·038	7·69	19·65	0·26	26·85	+0·36	227·78	·86
22	8·50	·038	7·66	19·58	0·27	26·76	0·38	271·64	·85

Greenwich Noon.		Semidiameter of Ball. Equat.	Phase.	Polar.	Semiaxis of Ring. Major.	Minor.	*Mimas.* a_1	b_1	l_1-L	Diff.
1892.		"	"	"	"	"	"	"	°	°
June	24	8·47	·037	7·64	19·52	0·29	26·67	0·40	315·49	·85
	26	8·44	·037	7·61	19·45	0·31	26·58	0·42	359·34	·84
	28	8·41	·036	7·59	19·38	0·33	26·49	0·45	43·18	·83
	30	8·38	·036	7·56	19·32	0·34	26·40	+0·47	87·01	763·83
July	2	8·35	·035	7·54	19·26	0·36	26·31	0·50	130·84	·83
	4	8·33	·034	7·51	19·19	0·38	26·23	0·53	174·67	·83
	6	8·30	·034	7·49	19·13	0·40	26·14	0·55	218·50	·82
	8	8·27	·033	7·46	19·07	0·43	26·06	0·58	262·32	·81
	10	8·25	·032	7·44	19·01	0·45	25·98	+0·61	306·13	·81
	12	8·22	·031	7·42	18·95	0·47	25·90	0·64	349·94	·81
	14	8·20	·030	7·40	18·90	0·49	25·82	0·68	33·75	·81
	16	8·17	·029	7·37	18·84	0·52	25·75	0·71	77·56	·80
	18	8·15	·029	7·35	18·79	0·54	25·67	0·74	121·36	·80
	20	8·13	·027	7·33	18·73	0·57	25·60	+0·78	165·16	763·80
	22	8·10	·026	7·31	18·68	0·59	25·53	0·81	208·96	·79
	24	8·08	·025	7·29	18·63	0·62	25·46	0·85	252·75	·79
	26	8·06	·024	7·27	18·58	0·65	25·39	0·88	296·54	·78
	28	8·04	·022	7·25	18·53	0·67	25·33	0·92	340·32	·79
	30	8·02	·021	7·24	18·49	0·70	25·26	+0·96	24·11	·78
Aug.	1	8·00	·020	7·22	18·44	0·73	25·20	1·00	67·89	·78
	3	7·98	·019	7·20	18·40	0·76	25·14	1·04	111·67	·78
	5	7·96	·018	7·18	18·36	0·79	25·08	1·08	155·45	·78
	7	7·94	·017	7·17	18·32	0·82	25·03	1·12	199·23	763·77
	9	7·93	0·016	7·15	18·28	0·85	24·98	+1·16	243·00	

Greenwich Noon.		*Enceladus.* a_2	b_2	l_2-L	Diff.	*Tethys.* a_3	b_3	l_3-L	Diff.
1892.		"	"	°	°	"	"	°	°
Mar.	2	38·65	+1·65	264·01	525·60	47·85	+2·05	175·425	381·535
	4	38·69	1·61	69·61	·61	47·89	1·99	196·960	·536
	6	38·72	1·56	235·22	·61	47·93	1·93	218·496	·537
	8	38·75	1·51	40·83	·61	47·96	1·87	240·033	·536
	10	38·77	1·46	206·44	·61	47·99	1·80	261·569	·536
	12	38·78	+1·41	12·05	·60	48·01	+1·74	283·105	·536
	14	38·79	1·36	177·65	·60	48·02	1·68	304·641	·535
	16	38·80	1·31	343·25	·60	48·03	1·62	326·176	·533
	18	38·79	1·26	148·85	·60	48·02	1·55	347·709	·532
	20	38·79	1·21	314·45	·60	48·01	1·49	9·241	·531
	22	38·77	+1·16	120·05	525·60	48·00	+1·43	30·772	381·529

Greenwich Noon. 1892.	*Enceladus.* a_2	b_2	l_2-L	Diff.	*Tethys.* a_3	b_3	l_3-L	Diff.
	″	″	°	°	″	″	°	°
Mar. 24	38·75	1·11	285·65	·59	47·97	1·37	52·301	·526
26	38·73	1·06	91·24	·59	47·94	1·31	73·827	·523
28	38·70	1·01	256·83	·59	47·90	1·25	95·350	·521
30	38·66	0·96	62·42	·58	47·86	1·19	116·871	·517
Apr. 1	38·62	+0·91	228·00	·58	47·81	+1·13	138·388	·514
3	38·58	0·87	33·58	·57	47·76	1·07	159·902	·510
5	38·53	0·82	199·15	·57	47·69	1·01	181·412	·506
7	38·47	0·78	4·72	·57	47·62	0·96	202·918	·502
9	38·41	0·73	170·29	·56	47·55	0·91	224·420	·498
11	38·34	+0·69	335·85	525·55	47·47	+0·86	245·918	381·493
13	38·27	0·65	141·40	·55	47·38	0·81	267·411	·488
15	38·20	0·61	306·95	·54	47·29	0·76	288·899	·483
17	38·12	0·58	112·49	·54	47·19	0·71	310·382	·478
19	38·04	0·54	278·03	·53	47·09	0·67	331·860	·473
21	37·95	+0·51	83·56	·53	46·98	+0·63	353·333	·467
23	37·86	0·48	249·09	·52	46·87	0·59	14·800	·461
25	37·76	0·45	54·61	·52	46·75	0·56	36·261	·456
27	37·66	0·42	220·13	·51	46·63	0·52	57·717	·450
29	37·56	0·40	25·64	·50	46·50	0·49	79·167	·443
May 1	37·46	+0·37	191·14	525·50	46·37	+0·46	100·610	381·437
3	37·36	0·35	356·64	·49	46·24	0·44	122·047	·432
5	37·25	0·33	162·13	·48	46·11	0·41	143·479	·425
7	37·14	0·32	327·61	·48	45·97	0·39	164·904	·418
9	37·02	0·30	133·09	·47	45·83	0·37	186·322	·412
11	36·91	+0·29	298·56	·46	45·69	+0·36	207·734	·406
13	36·79	0·28	104·02	·45	45·54	0·35	229·140	·399
15	36·67	0·27	269·47	·45	45·39	0·34	250·539	·393
17	36·55	0·26	74·92	·44	45·24	0·33	271·932	·387
19	36·43	0·26	240·36	·44	45·09	0·32	293·319	·380
21	36·31	+0·26	45·80	525·43	44·94	+0·32	314·699	381·373
23	36·18	0·26	211·23	·42	44·79	0·32	336·072	·367
25	36·06	0·26	16·65	·42	44·64	0·32	357·439	·361
27	35·93	0·26	182·07	·41	44·48	0·33	18·800	·354
29	35·81	0·27	347·48	·40	44·33	0·33	40·154	·348
31	35·68	+0·28	152·88	·40	44·17	+0·34	61·502	·341
June 2	35·56	0·29	318·28	·39	44·02	0·35	82·843	·335
4	35·43	0·30	123·67	·38	43·86	0·37	104·178	·329
6	35·31	0·31	289·05	·38	43·71	0·39	125·507	·323

Greenwich Noon. 1892.		*Enceladus.* a_2	b_2	l_2-L	Diff.	*Tethys.* a_3	b_3	l_3-L	Diff.
		"	"	°	°	"	"	°	°
June	8	35.18	0.33	94.43	.37	43.55	0.41	146.830	.317
	10	35.06	+0.34	259.80	525.37	43.40	+0.43	168.147	381.311
	12	34.93	0.36	65.17	.36	43.24	0.45	189.458	.306
	14	34.81	0.38	230.53	.35	43.09	0.47	210.764	.299
	16	34.69	0.41	35.88	.35	42.94	0.50	232.063	.294
	18	34.57	0.43	201.23	.35	42.79	0.53	253.357	.289
	20	34.45	+0.45	6.58	.34	42.64	+0.56	274.646	.283
	22	34.33	0.48	171.92	.33	42.50	0.60	295.929	.278
	24	34.21	0.51	337.25	.33	42.35	0.63	317.207	.272
	26	34.10	0.54	142.58	.32	42.21	0.67	338.479	.267
	28	33.98	0.57	307.90	.32	42.06	0.71	359.746	.262
	30	33.87	+0.60	113.22	525.31	41.92	+0.75	21.008	381.257
July	2	33.76	0.64	278.53	.31	41.79	0.79	42.265	.253
	4	33.65	0.67	83.84	.30	41.65	0.83	63.518	.248
	6	33.54	0.71	249.14	.30	41.52	0.88	84.766	.244
	8	33.43	0.75	54.44	.30	41.39	0.93	106.010	.239
	10	33.33	+0.79	219.74	.29	41.26	+0.97	127.249	.235
	12	33.23	0.83	25.03	.29	41.13	1.02	148.484	.231
	14	33.13	0.87	190.32	.28	41.01	1.07	169.715	.227
	16	33.03	0.91	355.60	.28	40.89	1.13	190.942	.223
	18	32.93	0.95	160.88	.27	40.77	1.18	212.165	.220
	20	32.84	+1.00	326.15	525.28	40.65	+1.23	233.385	381.216
	22	32.75	1.04	131.43	.27	40.54	1.29	254.601	.212
	24	32.66	1.09	296.70	.27	40.43	1.35	275.813	.209
	26	32.57	1.14	101.97	.26	40.32	1.41	297.022	.206
	28	32.49	1.18	267.23	.26	40.22	1.46	318.228	.203
	30	32.41	+1.23	72.49	.26	40.12	+1.52	339.431	.200
Aug.	1	32.33	1.28	237.75	.26	40.02	1.59	0.631	.197
	3	32.25	1.33	43.01	.25	39.93	1.65	21.828	.195
	5	32.18	1.38	208.26	.25	39.84	1.71	43.023	.192
	7	32.11	1.43	13.51	525.25	39.75	1.77	64.215	381.190
	9	32.04	+1.49	178.76		39.66	+1.84	82.405	

Greenwich Noon. 1892.		*Dione.* a_4	b_4	l_4-L	Diff.	*Rhea.* a_5	b_5	l_5-L	Diff.
		"	"	°	°	"	"	°	°
Mar.	2	61.28	+2.62	17.228	263.207	85.58	+3.66	245.888	159.515
	4	61.34	2.55	280.435	.208	85.66	3.55	45.403	.517
	6	61.39	2.47	183.643	.209	85.73	3.45	204.920	.518
	8	61.43	2.39	86.852	.210	85.79	3.34	4.438	.518

Greenwich Noon. 1892.	Dione. a_4	b_4	l_4-L	Diff.	Rhea. a_5	b_5	l_5-L	Diff.
	″	″	°	°	″	″	°	°
Mar. 10	61·47	2·31	350·062	·210	85·84	3·23	163·956	·519
12	61·49	+2·23	253·272	·210	85·87	+3·12	323·475	·520
14	61·50	2·15	156·482	·209	85·89	3·00	122·995	·519
16	61·51	2·07	59·691	·209	85·90	2·39	282·564	·519
18	61·51	1·99	322·900	·208	85·89	2·78	82·033	·518
20	61·49	1·91	226·108	·206	85·88	2·67	241·551	·518
22	61·47	+1·83	129·314	263·204	85·85	+2·56	41·069	159·516
24	61·44	1·75	32·518	·203	85·81	2·45	200·585	·515
26	61·40	1·67	295·721	·201	85·75	2·34	0·100	·513
28	61·35	1·59	198·922	·198	85·68	2·23	159·613	·511
30	61·30	1·52	102·120	·195	85·61	2·12	319·124	·508
Apr. 1	61·24	+1·44	5·315	·192	85·52	+2·02	118·632	·505
3	61·16	1·37	268·507	·189	85·41	1·92	278·137	·502
5	61·08	1·30	171·696	·185	85·30	1·82	77·639	·500
7	60·99	1·23	74·881	·182	85·18	1·72	237·139	·496
9	60·89	1·16	338·063	·177	85·04	1·62	36·635	·492
11	60·79	+1·10	241·240	263·173	84·90	+1·53	196·127	159·488
13	60·68	1·03	144·413	·169	84·74	1·44	355·615	·484
15	60·56	0·97	47·582	·164	84·57	1·36	155·099	·480
17	60·44	0·91	310·746	·160	84·40	1·28	314·579	·475
19	60·31	0·86	213·906	·154	84·22	1·20	114·054	·470
21	60·17	+0·81	117·060	·149	84·02	+1·13	273·524	·465
23	60·02	0·76	20·209	·143	83·82	1·06	72·989	·461
25	59·87	0·71	283·352	·138	83·61	1·00	232·450	·455
27	59·72	0·67	186·490	·133	83·40	0·94	31·905	·450
29	59·56	0·63	89·623	·127	83·18	0·88	191·355	·444
May 1	59·40	+0·59	352·750	263·121	82·95	+0·83	350·799	159·438
3	59·23	0·56	255·871	·114	82·71	0·78	150·237	·433
5	59·05	0·53	158·985	·109	82·47	0·74	309·670	·427
7	58·88	0·50	62·094	·103	82·22	0·70	109·097	·421
9	58·70	0·48	325·197	·095	81·97	0·67	268·518	·415
11	58·52	+0·46	228·293	·090	81·71	+0·64	67·933	·409
13	58·33	0·44	131·383	·084	81·45	0·62	227·342	·403
15	58·14	0·43	34·467	·078	81·19	0·60	26·745	·397
17	57·95	0·42	297·545	·071	80·92	0·58	186·142	·391
19	57·76	0·41	200·616	·066	80·65	0·57	345·533	·385
21	57·56	+0·41	103·682	263·059	80·38	+0·57	144·918	159·378
23	57·37	0·41	6·741	·052	80·11	0·57	304·296	·372

Greenwich Noon. 1892.		Dione. a_4	b_4	l_4-L	Diff.	Rhea. a_5	b_5	l_5-L	Diff.
		″	″	°	°	″	″	°	°
May	25	57·17	0·41	269·793	·046	79·84	0·57	103·668	·366
	27	56·97	0·42	172·839	·040	79·56	0·58	263·034	·360
	29	56·77	0·43	75·879	·034	79·28	0·59	62·394	·353
	31	56·57	+0·44	338·913	·027	79·00	+0·61	221·747	·347
June	2	56·37	0·45	241·940	·022	78·73	0·63	21·094	·341
	4	56·18	0·47	144·962	·015	78·45	0·66	180·435	·336
	6	55·98	0·49	47·977	·009	78·17	0·69	339·771	·330
	8	55·78	0·52	310·986	263·003	77·89	0·72	139·101	·323
	10	55·58	+0·55	213·989	262·997	77·62	+0·76	298·424	159·318
	12	55·39	0·58	116·986	·992	77·35	0·80	97·742	·311
	14	55·19	0·61	19·978	·986	77·07	0·85	257·053	·306
	16	55·00	0·64	282·964	·980	76·80	0·90	56·359	·300
	18	54·81	0·68	185·944	·974	76·54	0·95	215·659	·295
	20	54·62	+0·72	88·918	·969	76·27	+1·01	14·954	·289
	22	54·43	0·76	351·887	·964	76·01	1·07	174·243	·284
	24	54·24	0·81	254·851	·958	75·75	1·13	333·527	·278
	26	54·06	0·86	157·809	·954	75·49	1·20	132·805	·273
	28	53·88	0·91	60·763	·948	75·24	1·27	292·078	·268
	30	53·70	+0·96	323·711	262·943	74·99	+1·34	91·346	159·263
July	2	53·52	1·01	226·654	·938	74·74	1·41	250·609	·258
	4	53·35	1·07	129·592	·934	74·50	1·49	49·867	·253
	6	53·18	1·13	32·526	·929	74·26	1·57	209·120	·249
	8	53·01	1·19	295·455	·925	74·02	1·66	8·369	·244
	10	52·84	+1·25	198·380	·920	73·79	+1·74	167·613	·240
	12	52·68	1·31	101·300	·916	73·57	1·83	326·853	·235
	14	52·52	1·38	4·216	·912	73·35	1·92	126·088	·231
	16	52·37	1·44	267·128	·908	73·13	2·02	285·319	·227
	18	52·22	1·51	170·036	·904	72·92	2·11	84·546	·223
	20	52·07	+1·58	72·940	262·900	72·71	+2·21	243·769	159·218
	22	51·92	1·65	335·840	·896	72·51	2·31	42·987	·215
	24	51·78	1·73	238·736	·893	72·31	2·41	202·202	·211
	26	51·64	1·80	141·629	·890	72·12	2·51	1·413	·208
	28	51·51	1·88	44·519	·887	71·94	2·62	160·621	·205
	30	51·38	+1·95	307·406	·883	71·76	+2·73	319·826	·201
Aug.	1	51·26	2·03	210·289	·880	71·58	2·84	119·027	·198
	3	51·14	2·11	113·169	·878	71·41	2·95	278·225	·195
	5	51·02	2·19	16·047	·875	71·25	3·06	77·420	·192
	7	50·91	2·27	278·922	262·872	71·09	3·17	236·612	159·189
	9	50·80	+2·36	181·794		70·94	+3·29	35·800	

Approximate coordinates of Hyperion, referred to the axes of Saturn's Disc.

Greenwich. Noon. 1892.	x,	y,		x,	y,
	″	″		″	″
Feb. 11	−163·5	−11·0	Mar. 18	+197·9	− 4·0
12	207·3	8·5	19	156·3	5·8
13	237·3	5·4	20	100·8	7·0
14	252·2	− 2·1	21	+ 37·4	7·7
15	249·0	+ 1·3	22	− 28·8	7·7
16	227·4	4·6	23	93·2	7·2
17	187·5	7·4	24	151·3	6·2
18	131·0	9·6	25	199·4	4·9
19	− 61·9	10·7	26	234·5	3·3
20	+ 13·8	10·8	27	253·9	− 1·6
21	87·9	9·6	28	255·7	+ 0·2
22	152·7	7·2	29	238·8	1·8
23	197·7	4·1	30	203·2	3·3
24	219·3	+ 0·6	31	150·3	4·4
25	216·9	− 2·9	Apr. 1	83·5	5·0
26	191·9	6·1	2	− 8·2	5·1
27	148·6	8·6	3	+ 67·4	4·6
28	92·3	10·3	4	135·5	3·6
29	+ 28·7	11·1	5	186·8	2·3
Mar. 1	− 37·5	11·1	6	215·5	+ 0·7
2	101·0	10·4	7	+219·5	− 0·8
3	157·8	9·0	8	199·5	2·2
4	204·4	7·0	9	160·8	3·3
5	237·7	4·5	10	107·3	4·1
6	255·0	− 2·0	11	+ 45·1	4·5
7	254·6	+ 0·6	12	− 20·5	4·5
8	235·5	3·1	13	84·6	4·2
9	197·6	5·3	14	142·8	3·6
10	−142·7	7·0	15	191·6	2·9
11	− 74·5	7·9	16	227·6	2·0
12	+ 1·9	8·0	17	248·6	− 1·0
13	77·7	7·2	18	252·4	0·0
14	144·3	5·6	19	238·0	+ 0·9
15	192·6	3·4	20	205·1	1·7
16	219·2	+ 0·8	21	155·1	2·3
17	+220·2	− 1·7	22	− 91·0	+ 2·7

Greenwich Noon. 1892.	x_7	y_7		x_7	y_7
	"	"		"	"
Apr. 23	− 17·9	+ 2·7	Apr. 30	+162·5	− 1·7
24	+ 57·1	2·5	May 1	112·1	2·1
25	124·9	2·0	2	+ 52·2	2·3
26	177·5	1·3	3	− 11·5	2·4
27	208·5	+ 0·5	4	74·3	2·2
28	215·4	− 0·3	5	−131·9	− 2·0
29	+198·8	− 1·1			

The adopted zero meridian will pass the middle of the illuminated disc of *Saturn* at the following Greenwich mean times :—

1892.	h m	h m	1892.	h m	h m
Mar. 1	11 4·7	21 19·0	Mar. 29	4 35·0	14 49·4
2	7 33·3	17 47·6	30	1 3·7	11 18·0
3	4 1·9	14 16·2	31	7 46·7	18 1·0
4	10 44·8	20 59·1	Apr. 1	4 15·3	14 29·7
5	7 13·4	17 27·7	2	0 44·0	10 58·3
6	3 42·0	13 56·3	3	7 27·0	17 41·3
7	10 25·0	20 39·3	4	3 55·7	14 10·0
8	6 53·6	17 7·9	5	0 24·3	10 38·7
9	3 22·2	13 36·5	6	7 7·3	17 21·7
10	10 5·1	20 19·4	7	3 36·0	13 50·3
11	6 33·7	16 48·1	8	10 19·0	20 33·4
12	3 2·4	13 16·7	9	6 47·7	17 2·0
13	9 45·3	19 59·6	10	3 16·4	13 30·7
14	6 13·9	16 28·2	11	9 59·4	20 13·7
15	2 42·5	12 56·9	12	6 28·1	16 42·4
16	9 25·5	19 39·8	13	2 56·8	13 11·1
17	5 54·1	16 8·4	14	9 39·8	19 54·2
18	2 22·7	12 37·1	15	6 8·5	16 22·8
19	9 5·7	19 20·0	16	2 37·2	12 51·5
20	5 34·3	15 48·6	17	9 20·2	19 34·6
21	2 2·9	12 17·3	18	5 49·0	16 3·3
22	8 45·9	19 0·2	19	2 17·7	12 32·0
23	5 14·5	15 28·9	20	9 0·7	19 15·1
24	1 43·2	11 57·5	21	5 29·4	15 43·8
25	8 26·1	18 40·5	22	1 58·1	12 12·5
26	4 54·8	15 9·1	23	8 41·2	18 55·6
27	1 23·4	11 37·7	24	5 9·9	15 24·3
28	8 6·4	18 20·7	25	1 38·7	11 53·0

1892.	h m	h m	1892.	h m	h m
Apr. 26	8 21·8	18 36·1	June 4	4 11·3	14 25·8
27	4 50·5	15 4·8	5	0 40·2	10 54·6
28	1 19·2	11 33·6	6	7 23·4	17 37·9
29	8 2·3	18 16·7	7	3 52·3	14 6·7
30	4 31·1	14 45·4	8	0 21·1	10 35·5
May 1	0 59·8	11 14·2	9	7 4·4	17 18·8
2	7 42·9	17 57·3	10	3 33·2	13 47·7
3	4 11·7	14 26·0	11	0 2·1	10 16·5
4	0 40·4	10 54·8	12	6 45·4	16 59·8
5	7 23·5	17 37·9	13	3 14·2	13 28·6
6	3 52·3	14 6·7	14	9 57·5	20 11·9
7	0 21·0	10 35·4	15	6 26·3	16 40·8
8	7 4·2	17 18·6	16	2 55·2	13 9·6
9	3 32·9	13 47·3	17	9 38·5	19 52·9
10	0 1·7	10 16·1	18	6 7·3	16 21·8
11	6 44·9	16 59·2	19	2 36·2	12 50·6
12	3 13·6	13 28·0	20	9 19·5	19 33·9
13	9 56·8	20 11·2	21	5 48·4	16 2·8
14	6 25·6	16 40·0	22	2 17·2	12 31·7
15	2 54·4	13 8·8	23	9 0·6	19 15·0
16	9 37·5	19 51·9	24	5 29·4	15 43·9
17	6 6·3	16 20·7	25	1 58·3	12 12·7
18	2 35·1	12 49·5	26	8 41·6	18 56·0
19	9 18·3	19 32·7	27	5 10·5	15 24·9
20	5 47·1	16 1·5	28	1 39·3	11 53·8
21	2 15·9	12 30·3	29	8 22·7	18 37·1
22	8 59·1	19 13·5	30	4 51·6	15 6·0
23	5 27·9	15 42·3	July 1	1 20·4	11 34·9
24	1 56·7	12 11·1	2	8 3·8	18 18·2
25	8 39·9	18 54·3	3	4 32·7	14 47·1
26	5 8·7	15 23·1	4	1 1·5	11 16·0
27	1 37·5	11 51·9	5	7 44·9	17 59·3
28	8 20·7	18 35·2	6	4 13·8	14 28·2
29	4 49·6	15 4·0	7	0 42·7	10 57·1
30	1 18·4	11 32·8	8	7 26·0	17 40·4
31	8 1·6	18 16·0	9	3 54·9	14 9·3
June 1	4 30·4	14 44·9	10	0 23·8	10 38·2
2	0 59·3	11 13·7	11	7 7·1	17 21·6
3	7 42·5	17 56·9	12	3 36·0	13 50·5

1892.	h m	h m	1892.	h m	h m
July 13	0 4·9	10 19·4	July 17	6 29·4	16 43·9
14	6 48·3	17 2·7	18	2 58·3	13 12·8
15	3 17·2	13 31·6	19	9 41·7	19 56·1
16	10 0·5	20 15·0	20	6 10·6	16 25·0

The favourable opportunities of the present apparition of *Saturn* ought to be assiduously employed for careful observations of all the phenomena which may contribute to our better knowledge of the planet's system. Though exact measurements of both the coordinates of the relative positions of the satellites must be left to observers provided with superior micrometrical apparatus, most valuable results, not only for the orbits of the satellites, but also for the determination of the true dimensions of the ball and ring, may be obtained from careful estimations of the times of the conjunctions of the satellites with the end-points of the equatorial diameter and of the ring and also with one another. Observations of the conjunctions with the ball, or of the passages across the tangents parallel to the polar axis (the positions noted α β γ δ in the following list) are of greater importance than the doubtful estimations of ingress and egress at the transits and occultations, and it is to be hoped that many observers will take part. They will get no such favourable opportunities again before the year 1907.

1892.	G.M.T. h	
Mar. 1	8·7	Rh. γ
	11·9	Mi. ζ
	13·2	En. ζ
	17·0	Di. θ
	17·8	Mi. η
	19·0	Di. Ecl. D.
	19·5	En. η
	21·1	Te. ζ
	22·5	Di. α
	23·1	Te. β
	23·1	Mi. θ
2	10·5	Mi. ζ
	11·9	En. ϵ
	16·4	Mi. η
	19·8	Te. θ
	21·6	Te. Ecl. D.
	21·8	Mi. θ
	22·0	En. ζ
3	7·3	Di. γ
	8·1	Rh. Ecl. D.
	9·1	Mi. ζ
	9·5	Di. η
	12·3	Rh. α
	12·6	Titan θ
	14·5	En. θ
	14·8	Rh. ϵ
	15·0	Mi. η
	15·8	Titan Ecl. D.

1892.	G.M.T. h	
Mar. 3	18·4	Te. ζ
	20·4	Mi. θ
	20·4	Te. β
	20·8	En. ϵ
	22·3	Titan α
	23·3	Te. γ
4	10·7	Di. θ
	12·7	Di. Ecl. D.
	13·2	En. η
	13·6	Mi. η
	16·1	Di. α
	17·1	Te. θ
	18·3	Di. ϵ
	18·9	Te. Ecl. D.
	19·0	Mi. θ
	22·0	Te. α
5	9·7	En. ϵ
	12·0	Rh. ζ
	12·2	Mi. η
	14·6	Rh. β
	15·7	Te. ζ
	15·8	En. ζ
	17·6	Mi. θ
	17·7	Te. β
	18·4	Rh. γ
	19·5	Di. ζ
	20·6	Te. γ
	21·0	Rh. γ

1892.	G.M.T. h	
Mar. 5	21·7	Di. β
	22·1	En. η
	22·6	Te. η
6	8·2	En. θ
	10·8	Mi. η
	14·3	Te. θ
	14·6	En. ϵ
	16·2	Te. Ecl. D.
	16·2	Mi. θ
	19·2	Te. α
	21·2	Te. ϵ
	22·1	Mi. ϵ
7	6·4	Di. Ecl. D.
	7·0	En. η
	9·4	Mi. η
	9·8	Di. α
	12·0	Di. ϵ
	13·0	Te. ζ
	14·8	Mi. θ
	15·0	Te. β
	17·1	En. θ
	17·9	Te. γ
	18·2	Rh. θ
	19·9	Te. η
	20·6	Rh. Ecl. D.
	20·8	Mi. ϵ
8	8·1	Mi. η
	9·5	En. ζ

1892.	G.M.T. h	
Mar. 8	11·6	Te. θ
	13·1	Di. ζ
	13·5	Mi. θ
	13·6	Te. Ecl. D.
	15·3	Di. β
	15·9	En. η
	16·5	Te. α
	18·5	Te. ε
	18·6	Di. γ
	19·4	Mi. ε
	20·8	Di. η
9	8·3	En. ε
	10·3	Te. ζ
	12·1	Mi. θ
	12·3	Te. β
	15·2	Te. γ
	17·2	Te. η
	18·0	Mi. ε
	18·4	En. ζ
	22·0	Di. θ
10	6·8	Rh. γ
	8·9	Te. θ
	9·3	Rh. η
	10·7	Mi. θ
	10·8	En. θ
	10·9	Te. Ecl. D.
	13·8	Te. α
	15·8	Te. ε
	16·6	Mi. ε
	17·2	En. ε
11	6·8	Di. ζ
	7·6	Te. ζ
	8·3	Titan β
	9·0	Di. β
	9·3	Mi. θ
	9·6	Te. β
	9·6	En. η
	10·6	Titan Sh.
	12·3	Di. γ
	12·5	Te. γ
	14·2	Titan γ
	14·5	Di. η
	14·5	Te. η
	15·2	Mi. ε
	18·0	Titan η
	19·7	En. θ
	20·6	Mi. ζ
12	6·2	Te. θ
	6·5	Rh. θ
	7·9	Mi. θ
	8·2	Te. Ecl. D.
	9·0	Rh. Ecl. D.
	11·1	Te. α
	12·2	En. ζ
	12·9	Rh. α
	13·1	Te. ε
	13·8	Mi. ε
	15·5	Rh. ε

1892.	G.M.T. h	
Mar. 12	15·6	Di. θ
	17·8	Di. Ecl. D.
	18·5	En. η
	19·2	Mi. ζ
	21·1	Di. α
13	9·8	Te. γ
	10·9	En. ε
	11·8	Te. η
14	8·1	Di. η
	8·4	Te. α
	10·4	Te. ε
	11·0	Mi. ε
	12·7	Rh. ζ
	13·5	En. θ
	15·2	Rh. β
	16·4	Mi. ζ
	19·1	Rh. γ
	19·8	En. ε
	21·6	Rh. η
15	7·1	Te. γ
	9·1	Te. η
	9·3	Di. θ
	9·7	Mi. ε
	12·3	En. η
	14·7	Di. α
	15·1	Mi. ζ
	17·0	Di. ε
	21·0	Mi. η
16	7·7	Te. ε
	8·3	Mi. ε
	13·7	Mi. ζ
	14·8	En. ζ
	18·1	Di. ζ
	18·8	Rh. θ
	19·6	Mi. η
	20·3	Di. β
	21·1	En. η
	21·4	Rh. δ
17	6·4	Te. η
	6·9	Mi. ε
	7·2	En. θ
	12·3	Mi. ζ
	13·6	En. ε
	18·2	Mi. η
	22·1	Te. θ
18	8·3	Di. Ecl. R.
	8·4	Di. α
	10·6	Di. ε
	10·9	Mi. ζ
	16·1	En. θ
	16·8	Mi. η
	20·7	Te. ζ
19	7·4	Rh. γ
	8·5	En. ζ
	9·5	Mi. ζ
	10·0	Rh. η
	10·1	Titan θ
	11·7	Di. ζ

1892.	G.M.T. h	
Mar. 19	14·0	Di. β
	14·0	Titan δ
	14·9	En. η
	15·4	Mi. η
	17·2	Di. γ
	19·4	Te. θ
	19·4	Di. η
	19·9	Titan α
	20·8	Mi. θ
	21·4	Te. δ
	23·7	Titan ε
20	7·3	En. ε
	8·1	Mi. ζ
	14·0	Mi. η
	17·4	En. ζ
	18·0	Te. ζ
	19·4	Mi. θ
	20·0	Te. β
	20·6	Di. θ
	22·8	Di. δ
	22·9	Te. γ
21	7·1	Rh. θ
	9·7	Rh. δ
	9·9	En. θ
	12·7	Mi. η
	13·5	Rh. Ecl. R.
	13·6	Rh. α
	16·1	Rh. ε
	16·2	En. ε
	16·7	Te. θ
	18·1	Mi. θ
	18·7	Te. δ
	21·6	Te. Ecl. R.
22	7·6	Di. β
	8·6	En. η
	10·9	Di. γ
	11·3	Mi. η
	13·1	Di. η
	15·3	Te. ζ
	16·7	Mi. θ
	17·3	Te. β
	18·7	En. θ
	20·2	Te. γ
23	9·9	Mi. η
	11·2	En. ζ
	13·3	Rh. ζ
	14·0	Te. θ
	14·2	Di. θ
	15·3	Mi. θ
	15·9	Rh. β
	16·0	Te. δ
	16·4	Di. δ
	17·5	En. η
	18·9	Te. Ecl. R.
	19·7	Rh. γ
	19·7	Di. Ecl. R.
	20·9	Te. ε
	21·2	Mi. ε

1892.	G.M.T. h	
Mar. 23	21·9	Di. ε
	22·3	Rh. η
24	8·5	Mi. η
	10·0	En. ε
	12·6	Te. ζ
	13·9	Mi. θ
	14·6	Te. β
	17·5	Te. γ
	19·5	Te. η
	19·8	Mi. ε
	20·1	En. ζ
25	6·7	Di. η
	7·1	Mi. η
	11·3	Te. θ
	12·5	En. θ
	12·5	Mi. θ
	13·3	Te. δ
	16·2	Te. Ecl. R.
	18·2	Te. ε
	18·4	Mi. ε
	18·8	En. ε
	19·5	Rh. θ
	22·0	Rh. δ
26	7·9	Di. θ
	9·9	Te. ζ
	10·1	Di. δ
	10·1	Mi. θ
	11·3	En. η
	11·9	Te. β
	13·4	Di. Ecl. R.
	14·8	Te. η
	15·6	Di. ε
	16·8	Te. η
	17·0	Mi. ε
	21·4	En. θ
	22·4	Mi. ζ
27	2·0	Titan ζ
	5·9	Titan β
	8·5	Te. θ
	9·7	Mi. θ
	9·8	Titan Sh.
	10·5	Te. δ
	11·7	Titan γ
	13·5	Te. Ecl. R.
	13·8	En. ζ
	15·5	Te. ε
	15·5	Titan η
	15·6	Mi. ε
	16·7	Di. ζ
	18·9	Di. β
	20·1	En. η
	21·0	Mi. ζ
	22·2	Di. γ
28	7·2	Te. ζ
	8·1	Rh. γ
	8·3	Mi. θ
	9·2	Te. β
	10·6	Rh. η

1892.	G.M.T. h	
Mar. 28	12·1	Te. γ
	12·6	En. ε
	14·1	Te. η
	14·2	Mi. ε
	19·6	Mi. ζ
29	7·1	Di. Ecl. R.
	7·8	Te. δ
	9·2	Di. ε
	10·8	Te. Ecl. R.
	12·7	Te. ε
	12·9	Mi. ε
	15·1	En. θ
	18·3	Mi. ζ
	21·5	En. ε
30	6·5	Te. β
	7·6	En. ζ
	7·8	Rh. θ
	9·4	Te. γ
	10·4	Di. ζ
	10·4	Rh. δ
	11·4	Te. η
	11·5	Mi. ε
	12·6	Di. β
	13·9	En. η
	14·4	Rh. Ecl. R.
	15·8	Di. γ
	16·8	Rh. ε
	17·9	Mi. ζ
	18·0	Di. η
31	8·2	Te. Ecl. R.
	10·0	Te. ε
	10·1	Mi. ε
	15·5	Mi. ζ
	16·4	En. ζ
	19·2	Di. θ
	21·4	Di. δ
	21·4	Mi. η
Apr. 1	8·7	Te. η
	8·7	Mi. ε
	8·9	En. θ
	14·0	Rh. ζ
	14·1	Mi. ζ
	15·2	En. ε
	16·5	Rh. β
	20·0	Mi. η
	20·4	Rh. γ
2	6·2	Di. β
	7·3	Mi. ε
	7·3	Te. ε
	7·7	En. η
	9·5	Di. γ
	11·7	Di. η
	12·7	Mi. ζ
	17·8	En. θ
	18·6	Mi. η
3	10·2	En. ζ
	11·3	Mi. ζ
	12·8	Di. θ

1892.	G.M.T. h	
Apr. 3	15·0	Di. δ
	16·5	En. η
	17·2	Mi. η
	18·5	Di. Ecl. R.
	20·1	Rh. θ
	20·5	Di. ε
	21·7	Te. θ
4	7·7	Titan θ
	9·0	En. ε
	9·9	Mi. ζ
	11·6	Titan δ
	15·9	Mi. η
	(17·5	Titan α)
	17·6	Titan Ecl. R.
	19·1	En. ζ
	20·4	Te. ζ
	21·3	Mi. θ
	21·4	Titan ε
	21·7	Di. ζ
5	8·6	Mi. ζ
	11·5	En. θ
	14·5	Mi. η
	17·9	En. ε
	19·0	Te. θ
	19·9	Mi. θ
	21·0	Te. δ
6	8·7	Di. δ
	8·7	Rh. γ
	10·3	En. η
	11·3	Rh. η
	12·2	Di. Ecl. R.
	13·1	Mi. η
	14·2	Di. ε
	17·7	Te. ζ
	18·5	Mi. θ
	19·7	Te. β
7	11·7	Mi. η
	12·8	En. ζ
	15·3	Di. ζ
	16·3	Te. θ
	17·1	Mi. θ
	17·5	Di. β
	18·3	Te. δ
	19·2	En. η
	20·8	Di. γ
	21·4	Te. Ecl. R.
8	8·5	Rh. θ
	10·3	Mi. η
	11·0	Rh. δ
	11·6	En. ε
	15·0	Te. ζ
	15·4	Rh. Ecl. R.
	15·7	Mi. θ
	17·0	Te. β
	17·5	Rh. ε
	19·9	Te. γ
9	7·8	Di. ε
	8·9	Mi. η

1892.	G.M.T. h	
Apr. 9	13·6	Te. θ
	14·2	En. θ
	14·3	Mi. θ
	15·6	Te. δ
	18·7	Te. Ecl. R.
	20·2	Mi. ε
	20·5	En. ε
	20·5	Te. ε
10	9·0	Di. ζ
	11·2	Di. β
	12·2	Te. ζ
	12·9	En. η
	12·9	Mi. θ
	14·2	Te. β
	14·5	Di. γ
	14·6	Rh. ζ
	16·7	Di. η
	17·2	Te. γ
	17·2	Rh. β
	18·9	Mi. ε
	19·2	Te. η
	21·1	Rh. γ
11	10·9	Te. θ
	11·6	Mi. θ
	12·9	Te. δ
	15·5	En. ζ
	16·0	Te. Ecl. R.
	17·5	Mi. ε
	17·8	Di. θ
	17·8	Te. ε
	20·0	Di. δ
	23·7	Titan ζ
12	3·5	Titan β
	7·9	En. θ
	9·0	Titan Sh.
	9·3	Titan γ
	9·5	Te. ζ
	10·2	Mi. θ
	11·5	Te. β
	13·2	Titan η
	14·3	En. ε
	14·5	Te. γ
	16·1	Mi. ε
	16·5	Te. η
	20·8	Rh. θ
13	8·1	Di. γ
	8·2	Te. θ
	8·8	Mi. θ
	10·2	Te. δ
	10·3	Di. η
	13·4	Te. Ecl. R.
	14·7	Mi. ε
	15·1	Te. ε
	16·8	En. θ
14	8·8	Te. β
	9·2	En. ζ
	11·5	Di. θ
	11·7	Te. γ
Apr. 14	13·3	Mi. ε
	13·7	Di. δ
	13·7	Te. η
	15·6	En. η
	17·3	Di. Ecl. R.
	18·7	Mi. ζ
	19·2	Di. ε
15	9·4	Rh. γ
	10·7	Te. Ecl. R.
	11·9	Mi. ε
	12·0	Rh. η
	12·4	Te. ε
	17·3	Mi. ζ
	18·1	En. ζ
	20·3	Di. ζ
16	9·0	Te. γ
	10·6	En. θ
	10·6	Mi. ε
	11·0	Te. η
	16·0	Mi. ζ
	16·9	En. ε
17	7·3	Di. δ
	8·0	Te. Ecl. R.
	9·2	Mi. ε
	9·2	Rh. θ
	9·3	En. η
	9·7	Te. ε
	11·0	Di. Ecl. R.
	11·7	Rh. δ
	12·8	Di. ε
	14·6	Mi. ζ
	16·3	Rh. Ecl. R.
	18·2	Rh. ε
18	8·3	Te. η
	11·9	En. ζ
	13·2	Mi. ζ
	14·0	Di. ζ
	16·2	Di. β
	18·2	En. η
	19·1	Mi. η
	19·4	Di. γ
19	10·7	En. ε
	11·8	Mi. ζ
	15·4	Rh. ζ
	17·7	Mi. η
	17·9	Rh. β
	20·8	En. ζ
	21·8	Rh. γ
20	9·3	Titan δ
	10·4	Mi. ζ
	13·2	En. θ
	15·2	Titan α
	15·6	Titan middle of Ecl. of uncertain duration.
	16·3	Mi. η
	19·0	Titan ε
Apr. 20	19·5	En. ε
21	7·6	Di. ζ
	9·0	Mi. ζ
	9·8	Di. β
	12·0	En. η
	13·1	Di. γ
	14·9	Mi. η
	15·3	Di. η
	20·0	Te. ζ
22	13·5	Mi. η
	14·5	En. ζ
	16·5	Di. θ
	18·7	Di. δ
	18·7	Te. θ
23	12·2	Mi. η
	13·3	En. ε
	17·3	Te. ζ
	17·6	Mi. θ
	19·3	Te. β
24	9·0	Di. η
	10·1	Rh. γ
	10·8	Mi. η
	12·7	Rh. η
	15·8	En. θ
	16·0	Te. θ
	16·2	Mi. θ
	18·0	Te. δ
25	10·1	Di. θ
	12·3	Di. δ
	14·6	En. η
	14·6	Te. ζ
	14·8	Mi. θ
	16·2	Di. Ecl. R.
	16·6	Te. β
	17·8	Di. ε
	19·5	Te. γ
26	9·9	Rh. θ
	12·5	Rh. δ
	13·3	Te. θ
	13·4	Mi. θ
	15·3	Te. δ
	17·2	En. ζ
	17·2	Rh. Ecl. R.
	18·6	Te. Ecl. R.
	18·9	Rh. ε
	19·0	Di. ζ
27	11·9	Te. ζ
	12·0	Mi. θ
	13·9	Te. β
	15·9	En. ε
	16·8	Te. γ
28	7·2	Titan γ
	8·2	axis of Titan's shadow-cone just outside the ball.
	8·4	En. η

G.M.T.			G.M.T.			G.M.T.		
1892.	h		1892.	h		1892.	h	
Apr. 28	9·9	Di. Ecl. R.	Apr. 28	17·5	Te. ε	Apr. 29	16·1	Te. η
	10·6	Te. θ	29	9·2	Te. ζ		17·3	En. η
	10·6	Mi. θ		9·3	Mi. θ		18·1	Di. γ
	11·1	Titan η		10·9	En. ζ	30	9·7	En. ε
	11·5	Di. ε		11·2	Te. β		9·9	Te. δ
	12·6	Te. δ		12·6	Di. ζ		13·2	Te. Ecl. R.
	15·9	Te. Ecl. R.		14·1	Te. γ		13·8	Mi. ε
	16·1	Rh. ζ		14·8	Di. β		14·8	Te. ε
	16·6	Mi. ε		15·2	Mi. ε			

(To be concluded.)

Ephemeris of the Satellites of Uranus, 1892. By A. Marth.

		Ariel.				*Umbriel.*			
Greenwich Noon. 1892.	P	a_1	b_1	u_1-U	Diff.	a_2	b_2	u_2-U	Diff.
	°	"	"	°	°	"	"	°	°
Mar. 1	277·70	14·75	+11·14	185·25	1428·39	20·55	+15·52	267·40	868·68
11	277·81	14·86	11·19	173·64	·35	20·70	15·58	56·08	·65
21	277·94	14·95	11·21	161·99	·32	20·83	15·61	204·73	·62
31	278·09	15·02	11·20	150·31	·28	20·93	15·60	350·35	·60
Apr. 10	278·26	15·07	11·17	138·59	·26	20·99	15·56	141·95	·58
20	278·44	15·09	11·11	126·85	·23	21·02	15·48	290·53	·57
30	278·62	15·09	+11·03	115·08	·21	21·02	+15·37	79·10	·56
May 10	278·78	15·06	10·94	103·29	·20	20·98	15·24	227·66	·55
20	278·93	15·01	10·83	91·49	·20	20·90	15·09	16·21	·56
30	279·06	14·93	10·72	79·69	·19	20·80	14·93	164·77	·56
June 9	279·17	14·83	10·60	67·88	·20	20·67	14·77	313·33	·57
19	279·25	14·73	10·49	56·08	1428·20	20·52	14·61	101·90	868·59
29	279·29	14·61	+10·38	44·28		20·35	+14·46	250·49	

	Titania.				*Oberon.*				
	a_3	b_3	u_3-U	Diff.	a_4	b_4	u_4-U	U	B
	"	"	°	°	"	"	°	°	°
Mar. 1	33·71	+25·46	253·37	413·47	45·07	+34·05	191·93	357·105	+49·06
11	33·95	25·56	306·84	·45	45·40	34·18	99·27	·178	48·85
21	34·16	25·61	0·29	·42	45·68	34·24	6·59	·270	48·56
31	34·32	25·59	53·71	·41	45·90	34·22	273·89	·377	48·21
Apr. 10	34·43	25·52	107·12	·40	46·04	34·12	181·18	·494	47·82
20	34·48	25·39	160·52	·39	46·11	33·95	88·46	·615	47·41
30	34·47	+25·21	213·91	·39	46·10	+33·72	355·73	·735	+47·00
May 10	34·41	25·00	267·30	·40	46·01	33·43	263·00	·848	46·59
20	34·29	24·75	320·70	·40	45·85	33·10	170·28	357·950	46·21
30	34·12	24·49	14·10	·42	45·62	32·75	77·58	358·037	45·88
June 9	33·90	24·22	67·52	·43	45·34	32·40	344·88	358·107	45·60
19	33·65	23·96	120·95	413·45	45·01	32·05	252·20	358·157	45·39
29	33·38	+23·71	174·40		44·64	+31·71	159·55	358·183	+45·27

The values of P, a, b, $u-U$ being interpolated for the times for which the apparent positions of the satellites are required, the position-angles p and distances s of the satellites are found by means of the formulæ:

$$s \sin (p-P)=a \sin (u-U);$$
$$s \cos (p-P)=b \cos (u-U).$$

It is very desirable that some good positions of the satellites should be procured; the inner ones especially have been already too long neglected.

Col. Cooper's Observatory,
Markree, Collooney, Ireland.

Erratum in "Monthly Notices."

Vol. li., Appendix vii., pp. 176, 177, *for* Professor E. S. Holden, *read* The Lick Observatory.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LII. FEBRUARY 12, 1892. No. 4

Lieut.-General J. F. Tennant, C.I.E., R.E., F.R.S., President, in the Chair.

Bertram Bennett, B.A., Paignton, South Devon;
Charles Bright, F.R.G.S., Assoc.M.Inst.C.E., M.I.E.E., Telegraph Works, Silvertown, Essex;
Charles Burckhalter, Chabot Observatory, Oakland, California, and 962 Chester Street, Oakland;
Arthur Hilton Molesworth, B.A., 15 Park Lane, W.;
R. A. Sampson, B.A., St. John's College, Cambridge;
Charles Daulman Webb, B.A., B.Sc., King's College School, and 112 Adelaide Road, South Hampstead, N.W.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Louis Joyner, Bermuda (proposed by J. McCarthy);
Belgrave Ninnis, M.D., F.R.G.S., Deputy Inspector-General, Royal Navy, 46 Kensington Park Road, W. (proposed by Captain W. J. Ll. Wharton);
John Krom Rees, A.M., E.M., Director of the Observatory and Professor of Practical Astronomy and Geodesy, Columbia College, New York City (proposed by Professor A. W. Wright);
William James Watson, Gentleman, Morley House, South Stockton-on-Tees (proposed by Rev. W. Birks);
Elizabeth Brown, Further Barton, Cirencester (proposed by Captain W. Noble);
Alice Everett, M.A., 8 Gloucester Place, Greenwich, S.E., and Royal Observatory, Greenwich (proposed by A. M. W. Downing);
Annie Scott Dill Russell, 16 The Circus, Greenwich, S.E., and Royal Observatory, Greenwich (proposed by Edward W. Maunder).

Report of the Council to the Seventy-second Annual General Meeting of the Society.

The following table shows the progress and present state of the Society:—

	Compounders	Annual Subscribers	Mathematical Society	Total Fellows	Associates	Patron	Grand Total
December 31, 1890	239	374	3	616	48	1	665
Since elected	+11	+20	...	...	...	...	...
Deceased	−6	−5	...	...	−1	...	...
Resigned	−1	−9	...	...	...	...	...
Expelled	...	−9	...	...	...	...	...
Removals	+4	−4	...	...	...	...	...
December 31, 1891	247	367	3	617	47	1	665

Dr. Common's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, January 1, 1891 :—						
At Bankers', as per Pass Book	342	10	1			
Cheque not credited till 1891	2	2	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	6	0	9			
In hand of Assistant Secretary on Petty Cash Account	3	17	1			
				354	9	11
Dividends on £13,200 Consols, 2¾ per cent. ...	353	18	8			
,, on £212 9 2 New 2½-per-cent. Stock. ...	2	11	10			
,, on £1,250 Metropolitan Stock, 3 per cent.	36	11	4			
Interest on £200 on deposit at Bankers'	1	17	5			
				394	19	3
Received on account of Subscriptions :—						
Arrears	184	7	0			
254 Annual Contributions for 1891	533	8	0			
5 ,, ,, 1892	10	10	0			
34 Admission Fees	71	8	0			
21 First Contributions	33	12	0			
				833	5	0
17 Composition Fees				357	0	0
Sales of Publications :—						
At Williams & Norgate's, 1890	25	3	0			
At Society's Rooms, 1891	45	14	6			
				70	17	6
				£2,010	11	8

Audited and found correct, 1892 Jan. 6.

Robt. J. Lecky,
W. H. Maw.

Astronomical Society, from January 1 to December 31, 1891.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
" " for assistance in editing Society's Publications ...	50	0	0			
				300	0	0
Income Tax and House Duty	10	10	0			
Fire Insurance	7	16	6			
				18	6	6
Printing, &c.	557	0	0			
Engraving and Lithography	6	17	6			
				563	17	6
Computation of Ephemerides				50	0	0
Turnor and Horrox Fund: Purchases for Library	8	1	6			
Encyclopædia Britannica	27	15	0			
Binding Books in Library	9	17	0			
				45	13	6
Alterations, Decorating, and Repairs	26	5	6			
Sundry Fittings and Repairs	12	12	11			
				38	18	5
Lantern, &c., for Evening Meetings	34	2	0			
Ballot-boxes	7	15	6			
Re-covering and repairing Globes	5	16	0			
Lantern-slides	2	4	0			
				49	17	6
House Expenses	53	12	8			
Wages	44	8	0			
Postage	70	18	3			
Carriage of Parcels	1	7	2			
Stationery and Office Expenses	9	1	2			
Expenses of Meetings	20	0	0			
Coals and Gas	53	17	11			
Electric Lighting Expenses	1	13	4			
Rental of Wire for Time Signal, &c.	6	11	6			
Care of Fire-extinguishing Apparatus	3	8	9			
Sundries	5	4	0			
				270	2	9
Mrs. Jackson Gwilt's Annuity	8	19	0			
Lee and Janson Fund Grants	12	10	0			
				21	9	0
Purchase of £212 9 2 New 2½-per-cent. Stock at 94, including Commission				200	0	0
Bankers' Deductions on Cheques				0	1	11
Balances, December 31, 1891:—						
At Bankers', on current account	243	17	6			
" " on deposit	200	0	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	7	19	3			
In hand of Assistant Secretary on Petty Cash Account		7	10			
				452	4	7
				£2,010	11	8

Assets and Present Property of the Society, 1892 *January* 1.

	£ s. d.	£ s. d.
Balances, December 31, 1891:—		
At Bankers', on current account	243 17 6	
" " on deposit	200 0 0	
In hand of Assistant Secretary on account of Turnor and Horrox Fund	7 19 3	
In hand of Assistant Secretary on Petty Cash Account	0 7 10	
		452 4 7
Due on account of Subscriptions:—		
1 Contribution of 4 years' standing	8 8 0	
7 Contributions of 3 "	44 2 0	
36 " 2 "	151 4 0	
65 " 1 "	136 16 0	
	340 10 0	
Less 5 Contributions paid in advance ...	10 10 0	
		330 0 0
Due from Messrs. Williams & Norgate for sales of Publications during 1891		25 12 2
Due from Messrs. Wesley & Son, from sale of old non-astronomical books		12 18 0

£13,200 2¾-per-cent. Consols, including the Lee and Janson Fund, the Turnor Fund, the Horrox Memorial Fund, and Mrs. Jackson Gwilt's gift.

£212 9 2 New 2½-per-cent. Consols.

£1,250 Metropolitan 3-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments; Furniture.

Unsold Publications of the Society.

5 Gold Medals.

Trust Funds.

The Turnor Fund: A sum of 450*l*. $2\frac{3}{4}$-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of 100*l*. $2\frac{3}{4}$-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of 323*l*. 16*s*. 3*d*. $2\frac{3}{4}$-per-cent. Consols, the interest to be given by the Council to the widow or orphan of any deceased Fellow or Associate of the Society who may stand in need of it.

Mrs. Jackson Gwilt's Gift: 300*l*. $2\frac{3}{4}$-per-cent. Consols, subject to an annuity to the donor during her life of 8*l*. 19*s*. per annum.

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1891, and have found and certified the same to be correct. The cash in hand on Dec. 31, 1891, including the balance at the bankers' on current account, and a sum of 200*l*. on deposit, amounted to 452*l*. 4*s*. 7*d*.

The funded property of the Society has been increased by the purchase of 212*l*. 9*s*. 2*d*. New $2\frac{1}{2}$-per-cent. stock.

The books, instruments, and other effects have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, with the amount due against each Fellow's name.

Robt. J. Lecky,
W. H. Maw.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXX.	157	1
I. Part 2	42	...	XXXI.	140	...
II. Part 1	54	...	XXXII.	151	1
II. Part 2	20	...	XXXIII.	161	...
III. Part 1	65	1	XXXIV.	162	4
III. Part 2	84	1	XXXV.	107	5
IV. Part 1	77	3	XXXVI.	195	8
IV. Part 2	90	3	XXXVII. Part 1	337	8
V.	102	3	XXXVII. Part 2	283	8
VI.	121	3	XXXVIII.	268	1
VII.	142	3	XXXIX. Part 1	239	4
VIII.	126	3	XXXIX. Part 2	243	3
IX.	133	3	XL.	260	...
X.	143	...	XLI.	408	2
XI.	152	...	XLII.	232	3
XII.	159	...	XLIII.	235	2
XIII.	161	...	XLIV.	217	...
XIV.	365	2	XLV.	246	...
XV.	137	...	XLVI.	228	1
XVI.	163	...	XLVII. Part 1	3	...
XVII.	146	1	XLVII. Part 2	18	...
XVIII.	140	...	XLVII. Part 3	2	...
XIX.	147	...	XLVII. Part 4	10	...
XX.	139	...	XLVII. Part 5	10	...
XXI. Part 1	312	...	XLVII. Part 6	10	...
XXI. Part 2	98	...	XLVII.	209	1
XXI. 1 & 2 (together)	59	...	XLVIII. Part 1	248	3
XXII.	162	...	XLVIII. Part 2	258	2
XXIII.	145	...	XLIX. Part 1	471	2
XXIV.	153	...	XLIX. Part 2	201	4
XXV.	163	...	Index to *Memoirs*	644	...
XXVI.	170	...			
XXVII.	421	...			
XXVIII.	380	...			
XXIX.	398	1			

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	63	...	XXVII.	4	...
II.	65	...	XXVIII.	72	...
III.	...	...	XXIX.	52	...
IV.	...	...	XXX.	65	2
V.	...	...	XXXI.	93	...
VI.	50	...	XXXII.	115	5
VII.	2	...	XXXIII.	97	...
VIII.	153	1	XXXIV.	75	1
IX.	24	3	XXXV.	58	...
X.	178	1	XXXVI.	31	1
XI.	184	1	XXXVII.	38	3
XII.	106	2	XXXVIII.	101	2
XIII.	178	3	XXXIX.	97	1
XIV.	177	3	XL.	112	3
XV.	169	2	XLI.	111	5
XVI.	154	2	XLII.	120	1
XVII.	167	1	XLIII.	117	2
XVIII.	245	...	XLIV.	123	3
XIX.	57	...	XLV.	122	2
XX.	30	...	XLVI.	117	2
XXI.	17	...	XLVII.	135	5
XXII.	33	...	XLVIII.	127	3
XXIII.	19	...	XLIX.	121	11
XXIV.	24	...	L.	125	13
XXV.	15	...	LI.	123	17
XXVI.	11	...	Index ...	564	3

Library Catalogue 574

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LI. no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.

No. 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatoreal.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatoreal.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatoreal, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.

The *Sheepshanks* collection:—

„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.
„ 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Ys for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

No. 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

No. 51. (25) Ordinary 4½-inch compass with needle.
„ 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon, and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.
„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.

No. 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope with wooden tripod stand.

„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.

„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.

„ 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.

„ 91. Astronomical time watchcase, by Professor Chevallier.

„ 92. 2-foot protractor, with two movable arms, and vernier.

„ 93. Beam compass, in box.

„ 94. 2-foot navigation scale.

„ 95. Stand for testing measures of length.

„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.

„ 97. 12-cell Leclanché battery.

„ 98. 2-foot 6-inch navy telescope, with object-glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.

„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.

„ 100. 9-inch transit instrument, with level and iron stand.

„ 101. Small equatorial sight instrument, by G. Adams, London.

„ 102. Sun-dial, by Troughton.

„ 103. Sun-dial, by Casella.

„ 104. Sun-dial.

„ 105. Box sextant, by Troughton and Simms.

„ 106. Prismatic compass, by Schmalcalder, London.

„ 107. Compass, by C. Earle, Melbourne.

„ 108. Prismatic compass, by Negretti and Zambra.

„ 109. Dipleidoscope, by E. Dent.

„ 110. Abney level, by Elliott.

„ 111. Pocket spectroscope, by Browning.

„ 112. Universal sun-dial.

„ 113. Double sextant, by Jones.

„ 114. Two models, illustrating the effects of circular motions.

„ 115. A cometarium.

„ 116. A pair of 18-inch globes.

„ 117 }
„ 118 } Two old sun-dials.

No. 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. 3½-in. portable refracting telescope, by Tulley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil.
„ 129. Slater's improved armillary sphere, presented by Prof. Slater.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No.	4.		The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„	10.		Variation transit, to Mr. Maxwell Hall.
„	16.		The *Wollaston* telescope, to Mr. R. Inwards.
„	22.		The *Matthew* equatoreal, to Mr. J. Brett.
„	23.		The *Matthew* transit, to Captain W. Noble.
„	28.	(2)	6-inch theodolite and stand, to Dr. A. A. Common.
„	29.		Wire micrometer (No. 1), to Mr. C. Thwaites.
„	„		Wire micrometer (No. 2), to Mr. Maxwell Hall.
„	30.	(4)	3¼-inch equatoreal and stand, to Mr. E. B. Powell.
„	„	„	Double-image micrometer, to Mr. Maxwell Hall.
„	31.	(5)	2¾-inch telescope and stand, to Mr. F. J. Wardale.
„	34.	(8)	Transit instrument and stand, to Professor C. Pritchard.
„	38.	(12)	18-inch *Borda* repeating circle, to Mr. Maxwell Hall.
„	39.	(13)	8-inch repeating circle, to Mr. J. Norman Lockyer.
„	42.	(16)	Artificial horizon, roof, and mercury bottle, to Mr. C. Thwaites.
„	50.	(24)	Prismatic compass, to Mr. Maxwell Hall.
„	52.	(26)	Dipping needle, to Mr. Maxwell Hall.
„	54.	(28)	Magnetic intensity needle, to Mr. Maxwell Hall.
„	69.	(43)	Telescope, with rock-crystal object-glass, to Dr. W. Huggins.
„	78.		9¼-inch reflector and stand, to Mr. Maxwell Hall.
„	79.		Spectroscope, to Mr. Maxwell Hall.

No. 86.	4½-inch Gregorian reflector, by Short (two mirrors only), to Dr. A. A. Common.
" 99.	12-inch portable transit instrument, to Mr. H. T. Vivian.
" 120.	6-prism spectroscope, by Browning, to Mr. C. Thwaites.
" 123.	6-inch refractor, by Grubb, with three eyepieces, to Mr. W. E. Wilson.
" 124.	Position micrometer, by Cooke, and dark wedge, to the Rev. A. Freeman.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Professor G. H. Darwin for his work on Tides and their influence on the figures and motions of the Heavenly Bodies. The President will lay before the Society the grounds upon which the award has been founded.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associate during the past year:—

Fellows:—Prof. J. C. Adams.
Sir G. B. Airy.
Joseph Beck.
H. L. Boulton.
Dr. F. E. Brünnow.
Captain W. Chimmo.
Charles O. Dayman.
Albert Escott.
T. H. Hovenden.
Thomas Lee.
John Merrifield.
J. S. Nimkey.
N. R. Pogson.
Henry Pratt.
Benjamin Scott.
Lieut. Sidney G. Smith.
E. W. Snell.

Associate:—Eduard Schönfeld.

The obituary notice of the late Prof. J. C. Adams is deferred to the next Annual Report.

George Biddell Airy was born at Alnwick on 1801 July 27. He came of a stock whose home is in Kentmere, Westmoreland, where the Airys and Gilpins live to this day; and there is a record of the marriage at Kentmere of an Airy with a Gilpin in the fourteenth century. The particular branch from which George Biddell Airy sprang had, however, not lived in Westmoreland for some generations. His father, William Airy, was a Lincolnshire man, and somewhat late in life, at the age of about 50, had married Ann Biddell, of Playford, near Ipswich. There were three other children of this marriage, one of whom died in infancy. William Airy had a minor Government appointment, which took him into different parts of the country, and it was during a stay of three years at Alnwick that George was born. He went to school at Here-

ford, and afterwards to the Colchester Grammar School, and quite early manifested great ability, although in later life he would tell quaint stories which hinted that his sympathies were not entirely with the school curriculum. It may be that he learnt things more useful to him in his subsequent career in rambling about the farm at Playford, where his uncle, Arthur Biddell, insisted on his spending not only all his holidays but some considerable portion of the year as well. But his work at school was, at any rate, so exceptional that his uncle determined to send him to Cambridge, financial troubles having put this out of the power of his parents. He matriculated at Trinity College as a sizar on 1819 November 13, and after a brilliant career as an undergraduate, in the course of which he was elected Scholar of Trinity, he graduated as Senior Wrangler in 1823. There does not seem to have been any doubt from the first as to his outdistancing all the men of his year, although from his second term he supported himself by taking pupils in addition to his own work. He was elected a Fellow of Trinity College in 1824.

While still an undergraduate, Airy had contributed a paper to the Cambridge Philosophical Society on reflecting telescopes. This society had only been in existence about three years, having been founded, according to Prof. Sedgwick, by Dr. E. D. Clarke, Professor of Mineralogy; although the "first idea" was probably due to Sedgwick himself, who, while taking a tour in the Isle of Wight early in 1819 with Mr. Henslow, "deplored the want of some place in Cambridge to which those interested in science might resort with the certainty of meeting persons of similar or kindred tastes, and where they might learn what was being done abroad." * Airy's first paper, soon to be followed by a brilliant series, was received on 1822 November 25, and is printed in the second volume of the *Transactions*. Silvered glass meant in those days apparently always glass silvered at the back: and Airy shows how the double combination of lens and mirror in a Cassegrain telescope may be used to correct both chromatic and spherical aberration. In practice the idea does not seem to have been very successful, for he candidly confesses that on trying two 4-inch Cassegrain telescopes which he had constructed, "from some cause with which he was unacquainted, the image of a star or planet is surrounded with radiations which make the telescope quite useless for practical purposes." His next paper was read on 1824 March 15, after taking his degree, and he finds that the attraction of *Saturn's* ring should produce a flattening of the planet between the pole and the equator, which did not accord with the observations of Sir John Herschel. This was almost immediately followed by a beautifully simple investigation of the achromatism of eyepieces and microscopes. Such predecessors as Euler and Boscovich had practically made no advance towards the solution of this

* *Proc. Camb. Phil. Soc.* vol. vii. p. 2.

problem, and the subject had lain untouched for forty years; and yet the method explained by Airy in a few lines is so simple that it seems incredible that it should be so long overlooked. Three years later he returned to the theory of eyepieces and discussed their spherical aberration, and again showed his great power of "going to the root of the matter," to use a colloquial phrase with which his friends are familiar. He points out that the effects of spherical aberration are three: distortion of the object, curvature of the field, and bad definition away from the centre; and specifies three corresponding problems to be solved. A table at the end of the paper of practical rules for making eyepieces is also noteworthy.

He had written other papers showing great ability; one on Astigmatism, which he discovered in one of his own eyes, is of considerable importance. He suggested a perfectly successful method of correcting it by using a concave lens, one of whose surfaces, or both, were cylindrical; and this eminently practical suggestion involved him in a great mass of correspondence. Another paper contains some very pretty geometry of roulettes, to determine the proper shape for the teeth of cog-wheels, and appears to have been the first clear exposition of the important practical principles now universally recognised; and there are others on the figure of the Earth.

In 1826 the Lucasian professorship became vacant, and Airy was elected to it on 1826 December 7, so near the end of the year that in the Cambridge Calendar for 1828 the date of his election is given as 1827, though this is corrected in all other calendars. The successors of Barrow and Newton seemed to have gradually arrived at a somewhat liberal interpretation of their duties, though there are indications of a revival of activity just before Airy's time. In the calendar for 1802 we read, "No public lectures are delivered, but the (Lucasian) Professor is at all times accessible to students of any college, by whom he is frequently consulted." In 1826, however, and for some years previously, we find that "The Lucasian Professor gives a course of Mathematical lectures gratis." On Airy's appointment this becomes "The present Professor gives a course of experimental lectures," the fame of which has lasted to the present day; although the course was not many times repeated, for on 1828 February 6, Airy was made Plumian Professor of Astronomy and Experimental Philosophy, and Director of the new Observatory. It is curious that within a few years two men should have rapidly exchanged the one of these professorships for the other; for Woodhouse was elected to the Lucasian chair in 1820 and to the Plumian in 1822. The observatory was, doubtless, the attraction to both Woodhouse and Airy, although in 1822 it was only being built. The history of its foundation is thus told in the calendars of this period:

"A very general opinion having been entertained that it would greatly add to the utility and splendour of this University,

and might essentially promote the cause of science, to erect an observatory on the most approved plan, to be furnished with the best instruments that can be procured, measures were adopted, in 1820, to carry this idea into execution. The first step taken was to procure subscriptions from members of the University, and others, and by this means upwards of 6,000*l.* was obtained; a further addition to this sum was made by a Grace of the Senate 1820 May 5, by which 5,000*l.* was granted from the public chest in aid of this design." 4,000*l.* was added by a Grace 1824 June 4, and 3,115*l.* by a Grace 1824 December 8, according to the calendar for 1830. "At the same time regulations were made by which it was resolved that the superintendence and management of the observatory should be vested in the Plumian Professor, under whose direction two assistant observers should be placed." The assistants were to be graduates of the University, at salaries of 150*l.* and 100*l.*; and their duties were to consist principally in making meridional observations of the Sun, Moon, and fixed stars. It was further resolved "That the observations so made should each year, under the care of the Observer and his assistants, be printed and published at the expense of the University, and copies of the same presented to the principal observatories of Europe, viz.: Greenwich, Oxford, Dublin, Paris, Palermo. That in addition to the capital instruments of the observatory, there should be other instruments of less size and value appropriated to the use and instruction of academical students."

The erection of the observatory was commenced in 1822 and it was completed in 1824. However, when Airy was appointed Director, in 1828, very little had been done towards the fulfilment of this excellent programme. The only instruments were a couple of good clocks and a transit by Dollond; there were no assistants, and no observations had been published. The new Director at once entered upon his duties as defined in the above programme. He made observations with the transit instrument, and reduced and published them single handed. There seems to have been some difficulty about the assistants, and he accordingly induced the Senate in 1829 February, to revoke the former regulations and place the appointments in his hands, subject to the approval of the Vice-Chancellor. The first assistant, Mr. Baldrey, was appointed in 1829 June, at a salary of 80*l.* a year. At the same time, and apparently also at Airy's suggestion, the Senate appointed a Syndicate to visit the observatory once in each term, and to make an annual report to the Senate. The beneficial results of such an arrangement have been sufficiently recognised in its general adoption throughout the world.

The history of the observatory in these early years is worth studying in some detail as illustrating Airy's power of rapid organisation. He commenced residence at the Cambridge observatory on 1828 April 15, and was away from June 28 to September 17 on a scientific mission; and yet the volume

of observations for 1828 was published early in the following year, although "every part, from the making of the observations to the revising of the proof-sheets, was done by myself" (Camb. Obs. 1828: Preface). And it must be remembered that the best methods for making and reducing transit observations were then by no means clearly comprehended, even in what might be now regarded as essentials. A few extracts from the introductions to the first few volumes of Cambridge Observations will illustrate the early difficulties and the rapidity with which they were conquered better than any comments.

"In the management of the transit instrument it will be seen that I have adopted the laborious plan of applying numerical corrections for the errors of position, instead of relying on the mechanical removal of the errors. I believe that it is no more possible to keep the instrument exactly in position than to keep the clock exactly to sidereal time; and I have thought no trouble misplaced which gave greater accuracy to the results" (Camb. Obs. 1828).

"And I would warn future observers, who may wish to determine accurately the errors of their instruments, to place no confidence in catalogues, but to rely on the simple and independent methods which were used before even approximate catalogues were formed" (Ibid.).

"About this time I found, on examining the clock errors, that the transits of Polaris agreed in showing its assumed right ascension to be too great, by nearly $1^s{\cdot}2$" (Ibid.).

"The multiplication of the errors by the factors corresponding to the stars observed is always performed by means of a sliding rule" (Camb. Obs. 1829).

"The mural circle was mounted in 1832 October, and was divided by Mr. Simms upon its own pier in November of the same year. On 1833 January 5, the last essential parts were received, and on the next day observations were commenced. Mr. Glaisher, the assistant by whom the greater part of the circle observations had been made, arrived on the following day. The use of a mural circle was almost wholly new both to him and to myself: I believe, however, that very few of the observations are less satisfactory on this account" (Camb. Obs. 1833).

The last extract refers to a time when Airy had succeeded in getting the instrumental equipment of the observatory tolerably complete. A $3\frac{3}{4}$-inch equatoreal by Jones had been erected in 1832 June, and was used at once, principally for observations of *Jupiter's* fourth satellite, with the view of ascertaining *Jupiter's* mass. With the arrival of the mural circle the volumes of observations assume a form closely resembling that of the modern Greenwich volumes, so far as regards meridian work, occultations, and phenomena. The comparison is closer even as regards quantity than might be expected, for, during the year 1833, Mr. Baldrey observed about 5,000 transits and Mr. Glaisher about 5,000 zenith distances.

The mural circle, of course, brought new difficulties, notably the R−D discordance. Reflection observations of stars had been instituted by Pond at Greenwich about 1821, and the discordance had already been noticed, but not explained. Airy made a vigorous effort to trace it to its origin, but was fain to be content with an empirical formula; it must be admitted, however, that what escaped his sagacity has also eluded that of his successors to the present time.

Much information about this period may be gathered from the *Report on the Progress of Astronomy during the Present Century*, drawn up by Airy for the British Association at its second meeting in 1832. He "begs the indulgence of the Society since his own connection with astronomy is of short standing;" but it is difficult to imagine that the Report could have been more complete.

It is interesting to find how nearly simultaneous was the commencement of Airy's career with that of several institutions now familiar to us. We have already mentioned the foundation of the Cambridge Philosophical Society. The Royal Astronomical Society was founded in 1820; the *Astronomische Nachrichten* commenced in 1821; the Cape Observatory was planned by the Government in 1821 and finished in 1829; and the Parramatta Observatory in 1822. We read of the first transit circle being constructed for Bessel in 1820, and of Herschel's graphical method for reducing double stars in 1832, which Airy already recognises as "really a new step in science." On the other hand, there is much in the Report which sounds strangely in our ears. To a list of "all the public observatories with which he was acquainted," numbering 41, Airy appends the remark, "I am not aware that there is any public observatory in America, though there are some able observers," and the conclusion of the Report is mainly concerned with a serious complaint against English astronomers, on two grounds: "First, that in those parts of astronomy which depend principally on the assistance of Governments or powerful bodies, requiring only method and judgment, with very little science in the persons employed, we have done much; while in those which depend exclusively on individuals, we have done little. Secondly, that our principal progress has been made in the lowest parts of astronomy; while to the higher branches of the science we have not added anything."

For the grounds of this complaint we must refer to the Report itself; but one of them supporting the second charge is that "in England an observer conceives that he has done everything when he has made an observation; he thinks that anything beyond the very first stage of reduction ought to be left to others; . . . the reduction of Bradley's observations was left to a foreigner."

Airy certainly did his best to remove this national discredit, and the keenness with which he so early felt it must be remembered in studying his life. We have seen how actively he com-

menced the complete reduction of the observations at Cambridge; and it may be mentioned here that, besides his own observations, he afterwards reduced those of Groombridge, of Catton, and of Fallows; and we shall presently refer to the laborious reduction of the lunar and planetary results of Bradley, Bliss, Maskelyne, and Pond. Meanwhile, Airy had not neglected his more strictly professorial duties, nor his own scientific work. Immediately on his election as Plumian Professor he had instituted a series of lectures on practical astronomy at the observatory; and, although only a few minor scientific papers were written in the years 1827 to 1830, which we may presume to have been fully occupied with the organisation of observatory work, the following years produced a series of memoirs of first-rate importance in the establishment of the undulatory theory of light. Among the papers in the *Camb. Phil. Trans.* is one on the theory of circular object-glasses, which may be considered fundamental. The problem seems to have been evaded as too difficult by previous mathematicians. The case of a rectilinear aperture, or a rectilinear diaphragm covering an object-glass, had been worked out, "for though sometimes tedious it is never difficult." But in the theory of the circular object-glass a more difficult integral presents itself. Airy calculated this integral numerically for the first time. He never shirked an important piece of work of this kind. Some years later (1836–1838) he wrote a fine piece of mathematics on the intensity of light in the neighbourhood of a caustic, where he obtains expressions of great generality with admirable ease; but the importance of the paper lies chiefly in the numerical calculation which he undertook to complete it, and the manuscript of which fills a large volume, though the results are printed in a compendious table of a page. But this paper was written after he came to Greenwich, and we are now reviewing his Cambridge life. There are other papers on light in the *Philosophical Magazine*, including one on the achromatic centre of interference fringes, of great importance. But his most brilliant achievement was the memoir on the inequality of long period in the motions of the Earth and *Venus* (*Phil. Trans.* 1832), for which he obtained the Gold Medal of the Royal Astronomical Society in 1832. The work occupied him some years. The possibility of the existence of the inequality was first suggested to him by a study of the errors of Delambre's Solar Tables in 1827, when he had compared them with 1,200 Greenwich observations. The complete determination of the inequality required much labour, and we can well understand the tone of triumph in which the announcement of success was made to tho Royal Society: "Thus terminates one of the most laborious investigations that has yet been made in the planetary theory. . . . I believe that the paper now presented to the Royal Society contains the first specific improvement in the solar tables made in this country since the establishment of the theory of gravitation."

In the year 1835 the Astronomer Royal (Pond) resigned, and Airy was appointed his successor. A correspondence with Airy on the subject had been opened more than a year before, but Pond's resignation was delayed by circumstances then unforeseen. Meanwhile Airy's scientific services had been recognised by a pension from the Government, and it appeared doubtful whether he had anything to gain, even pecuniarily, by vacating the position which he had made famous at Cambridge for the more arduous duties of Astronomer Royal. His gratitude to the Government for the above-mentioned mark of recognition determined, however, his acceptance of Lord Auckland's offer in June 1835, and he was finally appointed Astronomer Royal on June 22. He took possession of the Royal Observatory on October 1. He did not leave Cambridge without many natural regrets, and his leave-taking was protracted by several circumstances. During the last two years he had been busily engaged in erecting the Northumberland equatoreal, presented to the Observatory by the Duke of Northumberland. It was not without some misgivings that Airy accepted the offer of the telescope, which he regarded as a possible temptation to neglect the fundamental meridian work of the Observatory. But, having accepted it, he lost no time and spared no labour to secure the efficiency of the telescope. An unfortunate accident delayed the work by many months: the flint lens was chipped in or after grinding, and M. Cauchoix had to reduce the thickness a quarter of an inch to grind out the fault, and in consequence to alter the figures of all four surfaces. It was thus not till some time after his appointment at Greenwich that Airy was enabled to report the completion of the mounting of the telescope, which he had begun and considered it his duty to finish. Again, his departure was so sorely felt by the University that his successor and others begged him to give one more set of lectures in the following spring; and though this involved an absence of five weeks from Greenwich and much extra labour, he obtained the necessary permission from the Admiralty and gave the lectures.

From the time of his appointment at Greenwich much of his life and work might be represented by a formula. The simplicity and directness of his character, which had revealed themselves in his mathematics, in the clearness of his literary style, and in the completeness of his fulfilment of any undertaking, now became apparent in the method and regularity with which he administered a large Government establishment. His early years were occupied by the orderly arrangement of the observatory as it stood, apart from the introduction of instrumental changes. He immediately instituted an annual Report to the Board of Visitors, and it is comparatively easy to gain from these Reports a general idea of the history of the Observatory. He set about arranging, binding, and cataloguing the manuscripts, and completed this work in 1841. That it was no mean labour may be gathered from the fact that "a practice was sometimes followed in Mr. Pond's time of taking books which had been only partially filled

by Dr. Maskelyne and inserting in the blank leaves calculations of a different date, and sometimes on very different subjects." He had already induced the British Association to obtain from the Government a grant for the reduction of the Planetary and Lunar Observations of Bradley, Bliss, Maskelyne, and Pond from 1750 to 1830, and this, though it must be dismissed here in a few words, was an immense labour. Ten or twelve computers were employed for many years under his supervision, forming a staff quite distinct from that of the Observatory. The work well deserved the award of the gold medal of the Royal Astronomical Society, which Airy received in 1847 for the Planetary Reductions, and the testimonial (equivalent to the Gold Medal) in 1848 for the Lunar Reductions.

The arrangement of the library at Greenwich was one of his first cares. The importance he attached to it may well be described in his own words, in which the spirit of his Report on Astronomy in 1833 is again made manifest: "The natural tendency, in an office so much pressed with routine work, and with official business having no very close relation to science, is to be degraded into a mere bureau of clerks; and it is difficult even for the director to resist the contagion. The only antidote is to place in the power of all the means of acquaintance with the literature and the foreign systems of astronomy; to make the principal persons, at least, familiar with the speculations of ancient and the theories of modern times. It is only thus that the character of an astronomer can be made to predominate over that of a mere observer or mere calculator" (Report for 1836).

In 1838 he obtained sanction for the provision of a Muniment or Record Room, in which to preserve manuscripts. From the first he made it a rule to transact business and give instructions almost entirely in writing, and to preserve *all* manuscripts. The advantages of this system have often appeared most unexpectedly; but it must be confessed that the rapid accumulation of volumes is a great drawback to its continuous adoption.

He also greatly extended the current system of reduction and publication, for which he found his Cambridge experience valuable. In 1841 he was thus enabled to say: "Within the last few years we have advanced little, or perhaps nothing, in the extent of our observations; but we have advanced greatly in the extent of our reductions. In a word, we have made little or no progress in the character of observers, but we have advanced very much in the character of astronomers," for the full meaning of which we must again refer to the Report of 1833. Finally, he reorganised the internal arrangements with regard to the observing duties of the assistants; and his new code of regulations was so successful as to be copied elsewhere.

Order having thus been established, Airy turned his attention to the improvement of the instrumental equipment. The Observatory having been originally instituted for improvement of lunar tables, he first devised an instrument, the

altazimuth, for observing the Moon more readily in the first and last quarters, when meridian observations can only rarely be made. We find his first proposal in a special address to the Board of Visitors in 1843, and at a special meeting in November 1843 his detailed scheme was approved. The instrument was not completed till May 1847, but meanwhile the whole arrangements for observation and reduction had been completely planned, and forms for reduction printed in detail, ready for the entry of the first observation in 1847, May 16, which have not been essentially modified since. In 1847 Airy determined to substitute a transit circle for the separate meridian instruments previously in use, and soon afterwards, having dismounted the zenith tube as inefficient, the idea of a reflex zenith tube occurred to him. These instruments were constructed during the next three years, and are still in use. The quality of workmanship demanded in their construction, especially that of the transit circle, taxed the skill of the mechanicians to the utmost. The necessary accuracy in the form of the pivots was only obtained, after many attempts, by carefully rubbing down by hand all places where a delicate spirit-level showed an excrescence, and each of the pivots cost six weeks of such labour. The completion of these instruments Airy regarded as a definite change in the Observatory equipment greater than any since Bradley's time. The chronograph, constructed from designs prepared entirely by himself, was introduced in 1854. In 1855 a circular was addressed to the Board of Visitors suggesting an improvement in the equatoreals, and a 12¾-inch object-glass was obtained from Merz, of Munich, and mounted on a massive framework according to the English system. The advantages of this system for strength and steadiness Airy had already recognised in mounting the Northumberland equatoreal at Cambridge, the designs for which he closely followed in the present instance. The characteristic of all Airy's instruments is great strength and solidity, and the mounting of this equatoreal is to be used for a 28-inch refractor now being made to replace the 12¾-inch.

With the inauguration of the South-east equatoreal terminated the entire change from the old state of the Observatory. In his report for 1859 Airy remarks: "There is not now a single person employed or instrument used in the Observatory which was there in Mr. Pond's time, nor a single room in the Observatory which is used as it was used then. In every step of change, however, except this last, the ancient and traditional responsibilities of the Observatory have been most carefully considered; and in the last the substitution of a new instrument was so absolutely necessary, and the importance of tolerating no instrument except of a high class was so obvious, that no other course was open to us. I can only trust that while the use of the equatoreal within legitimate limits may enlarge the utility and the reputation of the Observatory, it may

never be permitted to interfere with that which has always been the staple and standard work here."

Meanwhile other changes had taken place in the Observatory. A single computer, engaged experimentally in 1840, was found so useful that a number were gradually added to the regular staff. But more important than this was the addition of a new department for magnetic and meteorological observations. This was suggested in 1836, but not completely carried out till 1840, when the Royal Society recommended to the Treasury the importance of making a series of observations at some place near London, in general correspondence with Captain J. Clark Ross's surveying expedition to the Antarctic Ocean, in conformity with the plan drawn up by Professor Gauss, of Göttingen, for the simultaneous observation of the movements of the magnetic needle at various selected stations in both hemispheres. At Airy's instigation Greenwich was selected as this station, and in 1841 the new department was practically complete. Although instituted for a temporary purpose, its advantages and importance were soon so manifest that it became a regular part of the establishment, and has so remained. Observations were first made every two hours by the assistants; but the system of registration by photography was introduced in 1848, and relieved the severe labour previously necessary. The results of the magnetic observations have been summarised in several memoirs in the *Philosophical Transactions*. It is curious that in two of these, read in 1863 and 1868, Airy definitely gives his opinion that there was no evidence of a ten or eleven year period in the magnetic elements, such as would be demanded by a relation between sunspots and terrestrial magnetism; and it was not until 1879 that this relation was firmly established from the very same records by Mr. Ellis.

Another new department was added by Airy to the Observatory near the end of his career, and may be described as the Physical Department. In 1873 he commenced a systematic study of the Sun's surface by means of daily photographs, taken with a Kew photoheliograph; and in the same year a spectroscope was devoted to the determination of stellar motions in the line of sight; and thus for the first time equatoreal work became a part of the regular routine at Greenwich. The equatoreals had previously been used only occasionally—for the observation of occultations, phenomena of *Jupiter's* satellites, eclipses, and comets. It is to be remarked that the new departure was still in strict conformity with the duties of the Astronomer Royal as specified in the Royal Warrant, by which he is directed "to apply himself with the most exact care and diligence to the rectifying the tables of the motions of the heavens and the places of the fixed stars. . . ."

It has been above remarked that after the establishment of order and system in the observatory, Airy's life as actual Superintendent of the observatory work was so regular and methodical

as to leave little for the chronicler to remark. But his great energy found vent in a variety of other directions. Some of the extraneous work he did was doubtless not of his own seeking; though on reviewing his life one cannot but feel that between Airy and work there was always a mutual attraction. With his memoir "On the Intensity of Light near a Caustic," written soon after his departure from Cambridge, his purely scientific career, if this term may be applied to the production of theoretical investigations, practically closed; excepting only his Bakerian lecture in 1840 on "A new Polarity in Light." But his attention was occupied by many matters of great practical importance. In 1844 he thus sums up the extraneous calls on his time and energy: "Official superintendence, as Chairman of Committee, of the restoration of the national standards (of which the immediate superintendence is intrusted to Mr. Baily and Professor Miller). Reduction of the Irish tidal observations. Printing the account of Mr. Maclear's verification and extension of La Caille's arc. Assisting the Registrar-General in regard to the Meteorological Report affixed to the weekly Sanatory Report. Aiding Mr. Struve in his proposed determination of the longitude of Pulkowa. Arranging an enterprise to determine the longitude of Valentia in Ireland, for the measure of an arc of parallel, and for the fixing of a nautical zero."

The standards of length and weight had been destroyed in the great fire at the Houses of Parliament in October 1834, and the history of their restoration is given in the "Account of the Construction of the New National Standard of Length, and of its Principal Copies," drawn up by Airy in the *Phil. Trans.*, 1857. The work included the preparation and comparison of a large number of copies of the standards for distribution to public bodies in England and to foreign Governments, thus securing the legal standards against future loss from any possible accident to the national standards. The reduction of the Irish tidal observations was a most laborious piece of work; but space forbids more than the briefest reference to many of the things Airy did. The determination of the longitude of Pulkowa may be taken as representative of a long series of longitude determinations, both by chronometers and by telegraph, which Airy superintended, including Valentia, Cambridge, Edinburgh, Glasgow, Brussels, and Paris. At the end of the same Report (for 1844) we read of the important advice given to the Canada Boundary Commission. "The most difficult part of the boundary was a straight line of nearly seventy miles in length to join two defined points. The country through which this line was to pass is described as surpassing in its difficulties the conception of any European. It consists of impervious forests, steep ravines, and dismal swamps. A survey for the line was impossible, and a tentative process would have broken the spirit of the best men. I therefore arranged a plan of operations founded on a determination of the absolute latitudes and the difference of longitudes of the two

extremities. The difference of longitudes was determined by the transfer of chronometers by the very circuitous route from one extremity to the other; and it was necessary to divide the whole arc into four parts, and to add a small part by measure and bearing. When this was finished the azimuths of the line for the two ends were computed, and marks were laid off for starting with the line from both ends. One party, after cutting more than forty-two miles through the woods, were agreeably surprised, on the brow of a hill, at seeing directly before them a gap in the woods on the next line of hill; it opened gradually, and proved to be the line of the opposite party. On continuing the lines till they passed abreast of each other, their distance was found to be 341 feet. To form an estimate of the magnitude of this error, it is to be observed that it implies an error of only a quarter of a second of time in the difference of longitudes, and that it is only one-third (or nearly so) of the error which would have been committed if the spheroidal form of the earth had been neglected."

Two of Airy's greatest practical achievements are not referred to in this list: his investigation of the disturbance of the compass in iron ships, and his work in settling the gauge of railways. The correction of the compass for the influence of the iron of a ship was not a new question. There was already in existence the "Barlow plate," professing to correct the compass, but Airy pointed out the deficiencies of this and the remedy. In fact, he undertook an entirely independent investigation of the question, which was becoming important in consequence of the introduction of large quantities of iron in the construction of ships. In the year 1838 the iron steamship "Rainbow" was placed by the General Steam Navigation Company at his disposal, and the results of the elaborate series of experiments then made are published in a paper read to the Royal Society in 1839, in which, discussing these experiments, he gave a complete solution of the problem, and drew up a set of rules showing how in a simple and practical manner the compass could be made and maintained sensibly correct. This subject brought him afterwards a considerable correspondence, and in the year 1855 he communicated a further paper to the Royal Society, in which he discussed the compass errors of a number of different ships as observed in various parts of the world. The system as originally proposed by him in 1838 has, with some small modifications, been adopted by all other countries.

The only tangible recognition of this work which he ever received was a present of a gold snuff-box from the General Steam Navigation Company, "for his discovery of an effective corrector of the influence of local attraction upon the compass in iron steamships."

The work on railway-gauges occupied a considerable time, as may be seen from the "Astronomer Royal's Journal" for 1845. A Commission was appointed to inquire into the subject, and

many visits were paid to London for the hearing of evidence of all kinds; and in January 1846 experiments were made during a series of trial-trips at very high speeds. The final report was in favour of the present standard gauge, and in the present year (1892) the last broad gauge of the Great Western Railway, which alone has ever used any but the standard gauge, will disappear. Airy's railway experiments also included an investigation of the vibration effects caused in the surrounding soil, for the determination of the limits within which trains must not approach an observatory.

Another eminently utilitarian achievement was the connection, in the year 1852, of the Observatory with the general telegraphic system of the country, and the immediate establishment of a system of hourly time signals which were automatically transmitted from a clock at the Observatory (kept adjusted to exact Greenwich time) to the then principal electric telegraph centre in London for daily distribution by telegraph to different parts of London, and throughout the country along the different railway lines for the regulation of railway and public clocks, including the daily dropping of a time-ball at Deal for giving time to shipping in the Downs. This system was the precursor of similar systems in other countries.

But it was not only in matters of practical importance such as these that his energies overflowed. Besides paying the most careful attention to current astronomical events, which yet fell outside the routine work at Greenwich (such as total solar eclipses, of which he personally observed that of 1842 at Turin, that of 1851 at Gottenburg in Norway, and that of 1860 at Hereña in Spain), he was chiefly responsible for the carrying out of two great scientific investigations—the determination of the Earth's density by pendulum experiments at the Harton Colliery in 1854, and the determination of the solar parallax by observations of the transit of *Venus* in 1874. Both these had been long contemplated. The Harton Colliery experiments were the successful issue of a third attempt after two failures. In 1826 Airy and Whewell had commenced operations in the Dolcoath mine, one of the deepest in Cornwall, where they were to observe the swinging of pendulums at the top and bottom of the mine for the comparison of the effects of gravity at these points. The accident which interrupted them is thus described: "We were raising the lower pendulum up the south shaft for the purpose of interchanging the two pendulums, when (from causes of which we are yet ignorant) the straw in which the pendulum-box was packed took fire, the lashings were burnt away, and the pendulum with some other apparatus fell to the bottom. This terminated our operations of 1826."

With three other observers the experiments were again attempted in 1828, but were suddenly stopped by the occurrence of a "fall" in the mine, and the consequent flooding of the lower station by the rise of the water. No further attempt was

made till 1854, when the introduction of chronographic registration had afforded new facilities for comparing clocks at the top and bottom of the mine. The account of the operations is given in the *Phil. Trans.* for 1856. It was found that the pendulum at the bottom of the mine would gain $2\frac{1}{4}$ seconds per day on that at the top; or, in other words, gravity was greater at the bottom of the mine than at the top by $\frac{1}{19190}$ part; and from a knowledge of the density of the stratum of the Earth's surface pierced by the mine it was concluded that the Earth's mean density was 6·6 times that of water.

It is now somewhat difficult to realise the intense anxiety with which astronomers looked forward to the pair of transits of *Venus* of the present century. It was hoped that the solar parallax would be determined with the greatest precision if only proper care were taken in the observations; for it was thought that the foreknowledge of the phenomena of the "black drop," which had been gained by a study of the observations made in 1761 and 1769, would be sufficient to enable observers to guard against this disturbing cause. Airy could certainly not be accused of delay in considering the necessary preparations and precautions. In 1857 he opened a discussion as to the best means of observing the transits of 1874 and 1882 by a paper read to the Royal Astronomical Society. In 1865 we find him already looking beyond the transit of 1874 to warn the Board of Visitors that "in reference to possible observations of the transit of *Venus* in 1882, it will be necessary in no long time to examine the coasts of the Great Southern Continent."

The British expeditions were arranged and equipped under his guidance, and his "Instructions to Observers" are a model of what such documents should be. There were to be five "Districts": Egypt, the Sandwich Islands, Rodriguez, Christchurch (New Zealand), and Kerguelen Island; and these were subdivided into several stations. The numerous observers were trained for many months, before starting for their destinations, at the Royal Observatory; and although Colonel Tupman undertook a great deal of the labour of supervision, the whole enterprise was a serious addition to the work of the Astronomer Royal. A model was constructed to show the phenomena of the transit, and the observers all practised diligently with it. That the results for the actual transit were not so satisfactory as had been hoped was in no way due to any want of care in organisation, but to the unforeseen influence of the illuminated atmosphere of *Venus*. But for this, the world would have been in no danger of forgetting that it was in great measure due to Airy's influence that the Government aided so lavishly what promised at one time to be the most important astronomical adventure of this century.

It has been remarked that Airy's purely scientific work practically terminated with his Cambridge career. His determination of the motion of the solar system in space from the average drift of 1,167 stars must be regarded rather in the light of a direct

deduction from the regular routine of observation at Greenwich than as an original investigation, although the method of procedure was sufficiently new to be still quoted as Airy's method. In 1870 we find him looking back with some regret on the change in his life and work involved in his appointment to the post of Astronomer Royal. "I have often felt," he remarks to the Board of Visitors, "the desire practically to refresh my acquaintance with what were once favourite subjects—Lunar Theory and Physical Optics. But I do not at present clearly see how I can enter upon them with that degree of freedom of thought which is necessary for success in abstruse investigations." His life had indeed been a busy and distracted one; it is hard to believe that it was not spent in the right way, for the setting of things in order, if not the work he loved best, was accepted so willingly as his life work that he was equally content in correcting solar tables, in organising a great expedition, or in labelling a number of boxes "empty." And yet he would often smilingly protest to his friends that he was intended for a life of quiet and contemplation—"he ought to have been a rural dean." It is possible that his work at Greenwich influenced him more than he himself suspected; for when the longing to resume his work of earlier days came upon him in 1870, it crystallised into the undertaking of a laborious research in lunar theory for which his failing powers ultimately proved inadequate. The fundamental conception of his numerical lunar theory was worthy of him; but the carrying out of this conception involved a close attention to a most intricate series of calculations which was not possible at the age of eighty. If it be sad to see a man die in the ripeness of his age, it is sad to read Airy's final confession that the completion of the task was beyond him; but it is the more clearly apparent that he toiled unremittingly until he could toil no more.

We have omitted to speak of many things which would be important in the lives of most men, but are trifles in that of a giant. Airy was a voluminous writer from the time when he was appointed Lucasian Professor onwards. His volume of *Mathematical Tracts*, published in early Cambridge days, and dealing with Lunar Theory, Figure of the Earth, Precession and Nutation, and Calculus of Variations, to which were added, in the second edition, Planetary Theory and the Undulatory Theory of Optics, was practically the first of Cambridge text-books in the modern sense. Other text-books were written later, notably one on Magnetism, on which he delivered a course of lectures at Cambridge in 1869. He then remarked that the novelty of the subject and the want of adequate text-books for students made lecturing difficult. Besides articles on Trigonometry and Figure of the Earth, Airy contributed a very valuable article on "Tides and Waves" to the *Encyclopædia Metropolitana*. In this he attacked Laplace's celebrated solution of the problem of the tidal oscillations of an ocean of uniform depth. This attack drew forth a defence from Sir

William Thomson, and (although Airy continued to adhere to his own view) it may be suspected that Airy's opinion would now command the assent of but few competent mathematicians. His treatment of the problems involved in the propagation of waves in rivers and estuaries, and of the other phenomena of wave motion, forms an important and original contribution to hydrodynamical science. This portion of the memoir led him on to an approximate treatment of the general tidal problem, presumably in substitution for the rejected Laplacian theory, in which the ocean is treated as consisting of a number of zonal canals. The conclusions attained are of some general interest, but are avowedly remote from the actuality on the Earth's surface. If Laplace's theory be accepted, the value of this part of the paper falls considerably. It is now generally considered that the most original and important portion of the whole is that which treats of waves; but the article on "Tides and Waves" has been for many years the leading compendium of tidal theory and practice, and, notwithstanding the advance of science since it was written, still retains much of its value.

His miscellaneous writings include essays on the locality in which Julius Cæsar first landed in Britain, and other archæological questions.

He was also an excellent public lecturer, and could expound in a charming way either the swinging of pendulums for determination of the mean density of the Earth or the manner in which the Sun's distance may be determined from transits of *Venus*; and his useful and well-known work, *Popular Lectures on Astronomy*, is the reproduction, from shorthand notes, of six lectures delivered at the Museum at Ipswich in 1848, when such lectures were almost unknown. The work is still held in much favour.

The list of Airy's honours and distinctions is a long one. He was several times President of the Royal Astronomical Society, twice received its Gold Medal, and once the equivalent of a Gold Medal. He was President of the Royal Society, and received a Copley and a Royal Medal. He was awarded the Lalande Medal of the French Academy, and was one of its eight Foreign Associates. He was made C.B. in 1871 and K.C.B. in 1872, July 30, and was shortly afterwards knighted by her Majesty the Queen at Osborne. In 1875 he received the Freedom of the City of London (which had never before been conferred for scientific distinction), "as a recognition of his indefatigable labours in Astronomy, and of his eminent services in the advancement of practical science, whereby he has so materially benefited the cause of commerce and civilisation." He was a D.C.L. of Oxford, an LL.D. of Cambridge and Edinburgh, and an Honorary Fellow of Trinity College, Cambridge. He was a Chevalier of the Order Pour le Mérite of Prussia, of the Legion of Honour of France, of the Polar Star of Sweden, of the Dannebrog of Denmark, of the Rose of Brazil, and was the recipient of many personal favours, not the least of which was a present from

the Emperor of Russia of a gold cigarette-box set with diamonds. His collection of medals and decorations numbers nearly thirty altogether.

He married, on March 30, 1830, Richarda, daughter of the Rev. Richard Smith, of Edensor, county Derby. Lady Airy died on August 13, 1875, a few days after the celebration of the bi-centenary of the foundation of the Royal Observatory. There were nine children of the marriage. The first three, all born at Cambridge, died early; the others—three sons and three daughters—are all living. One daughter is the wife of Dr. Routh, of Cambridge; the other two are unmarried, and were the constant companions of their father in his old age, more especially after his retirement from the Royal Observatory. He resigned his appointment as Astronomer Royal on August 15, 1881, in his eightieth year, and forthwith retired to the White House, on Croom's Hill, just outside the wall surrounding Greenwich Park; and here for ten years he passed a tranquil existence, varied only by regular visits to his country house at Playford, which had been customary for many years. He had a great affection for the neighbourhood in which his early days were spent, and was in return regarded with great veneration by the country-side. Writing to a local paper after his death, the present head-master of the Colchester Grammar School laments that, owing to irregularity in keeping the school register, no record remains of Airy's presence there; "and the present school building and plant are long subsequent to his time, so that no 'G. B. A.,' carved in wood or brick, remains a silent witness to his early energy." Just before his death his thoughts reverted constantly to these early days, and he would recall incidents, such as seeing Wellington's country recruits coming to have their hair cut in Colchester Castle-yard, which remind us how nearly his life spanned the nineteenth century. At the age of ninety he was in perfect physical health, and not only welcomed a large party of friends at the White House, but publicly performed the ceremony of lighting with gas the parish clock of Greenwich for the first time. An accidental fall some months afterwards, in his house at Playford, prostrated him for some time. He returned to Greenwich; but there internal complications developed which necessitated a serious surgical operation, and though for a time he appeared to rally, his strength gradually ebbed away, and he died on Saturday afternoon, January 2, 1892. He was buried in the churchyard at Playford on Thursday, January 7, with his wife and close to his three children.

H. H. T.

Joseph Beck was born at Stamford Hill in June 1829. He finished his school training at York, and on leaving there he was apprenticed to the well-known optical firm of Troughton and Simms. At the conclusion of his apprenticeship he became a partner in the firm of Smith and Beck, opticians, which

subsequently became known as that of R. and J. Beck, of Holloway and Cornhill.

After his marriage, in 1856, he lived in Stoke Newington, in which district he resided till his death, and always took an active interest in local affairs. He was one of the livery of the Goldsmiths' Company, and in 1873 was elected Common Councillor for the Ward of Cornhill. He also filled many other important offices connected with the Corporation, and was universally respected, not only as a zealous public servant, but as a man of high character and honesty of purpose.

As one of the leading opticians in the City he was thoroughly acquainted with the scientific aspects of his business, in which he was actively engaged during most of his life. He died of pneumonia after a few days' illness on April 18, 1891.

Mr. Beck was a Fellow of the Royal Microscopical Society, and was elected a Fellow of this Society on February 8, 1861.

Henry Lord Boulton was born December 31, 1829. A considerable portion of his life was spent in South America, and for the last twenty years he held the delicate and responsible position of English Consul-General at Venezuela. He was also chief partner in the Venezuelan banking house of H. L. Boulton & Co., of Carácas, who collect and remit to London the monthly instalments for the service of the Venezuelan debt. His death removes a valuable consular officer, whose prestige in Venezuela and knowledge of the country marked him out as specially competent to assist in the settlement of the boundary dispute between that country and Great Britain. Mr. Boulton died November 26, 1891. He was elected a Fellow of this Society January 11, 1889.

Franz Friedrich Ernst Brünnow was born in Berlin on November 18, 1821, being the son of Johann Brünnow, a Privy Councillor of State. He attended the Friedrich-Wilhelm Gymnasium from 1829 to 1839, when he entered the Berlin University, attending the lectures of Dirksen, Lejeune-Dirichlet, Ohm, and Steiner in Mathematics, Encke in Astronomy, and Dove in Physics. In 1843 he received the degree of Ph.D., his doctorial thesis being entitled "De Attractione Moleculari." Under the direction of Encke, Brünnow took a zealous part in the astronomical work of the Berlin Observatory, of which his numerous papers in the *Astron. Nachrichten* give evidence. He thus became, early in life, one of the band of earnest astronomers that Encke had gathered round himself at Berlin, including such well-known names as those of Galle, Bremiker, and D'Arrest. It is stated of Brünnow that he was present in the Berlin Observatory when Neptune was first recognised as a planet, and that one of the first notifications of its discovery that reached England was from him.

In the spring of 1847 he removed to Bilk, near Düsseldorf,

on his appointment as Director of the observatory at that place. During his residence here he published his well-known memoir on De Vico's comet, for which he received the Gold Medal of the Amsterdam Academy. It was during this period also that the excellent *Lehrbuch der sphärischen Astronomie* was prepared; the first edition, containing a preface by Encke, was published in Berlin in 1851. This text-book eventually reached a fourth edition, and was translated into English by Main, the Radcliffe Observer at Oxford, in 1860 (this translation contains Part I. of the original work only), into English by Brünnow himself in 1865, and has also, it is stated, been translated into Russian, Italian, and Spanish. These facts speak for themselves as to the estimation in which the *Lehrbuch* was (and is still) held by astronomers. It has perhaps done more to establish the fame of Brünnow than any of his other works.

In 1851 Galle was appointed Director of the Breslau Observatory, and on his departure from Berlin Brünnow took his place at the observatory as first assistant, in which capacity he remained from November 1851 to 1854. It was during this time that he computed the tables of *Flora*, based on Encke's method of procedure as given in the *Berliner Jahrbuch* for 1857. In later years, 1859 and 1869 respectively, tables of *Victoria* and *Iris* followed, the tables of the last-named planet being published at the expense of the Royal Astronomical Society. His work on the theory of these minor planets showed Brünnow to be a calculator of a high order, imbued with the best methods of the modern German school, as was indeed to be expected from a pupil—and evidently a favourite pupil—of Encke.

But a more independent position was soon to be his. In 1854 Brünnow was offered the post of Director of the new observatory in process of erection at Ann Arbor, Michigan, which he accepted. Whilst here he published for a short time a periodical under the title *Astronomical Notices*; it first appeared in Ann Arbor, afterwards in Albany, N.Y., whither he went in 1860 as Associate Director of the observatory in that town. Brünnow returned to Ann Arbor in 1861, and devoted himself to the study of the physical and astronomical constants of the observatory and of the instruments in it. His work on the errors of the circles of the Ann Arbor meridian instrument is perhaps not to be surpassed for thoroughness by anything similar to be found in the whole range of astronomical literature. The investigation was published in the *Astronomical Notices*.

Brünnow's relations to Watson (afterwards his successor at Ann Arbor) were very intimate and cordial. For a long time Watson was the only member of his class, and Brünnow assiduously delivered lectures to that class. It is said that it was at that time a common sight to see the professor talking in an enthusiastic and excited manner to the attentive class of one. When asked why he devoted so much time to so small a class, Brünnow replied: "That class consists of Watson." This high

estimate of his pupil's ability was, as is well known, fully justified by Watson's subsequent career.

In 1863, after the outbreak of the war, Brünnow resigned his position at Ann Arbor, and in 1865, on the death of Sir W. Hamilton, was appointed Andrews Professor of Astronomy in the University of Dublin, and Royal Astronomer for Ireland.

The work of organising the Dunsink Observatory and of placing it on a modern footing fell to the lot of Brünnow, who proved himself thoroughly competent to carry out the needed reforms. Under his direction the South object-glass of $11\frac{3}{4}$ inches aperture was mounted so as to form an excellent equatoreal telescope, and with it he carried out his well-known researches on stellar parallax, which testify so highly to his skill and assiduity as an observer.

The first and second parts of *Astronomical Observations and Researches made at Dunsink* were published by Brünnow in 1870 and 1873 respectively, and contain the results of his work with the South refractor. They are models of what such publications ought to be, lucid in arrangement, clear in exposition, every part of the work given in sufficient detail to enable anyone, with but little trouble, to follow the various steps of the reductions. The stars to which he devoted particular attention were *α Lyræ*, *σ Draconis*, *Groombridge* 1830, 85 *Pegasi*, and *Bradley* 3077; and his work on these brought out clearly the high order of accuracy attainable by a skilled observer in observations of differences of declination with a micrometer. The third part of the above-mentioned publication contains some additional observations made by Brünnow during his tenure of office, which were edited and published by his successor, Sir R. Ball, the present Royal Astronomer for Ireland.

In 1874 Brünnow resigned his position in Dublin on account of failing health and eyesight. He retired first to Basle, then in 1880 he removed to Vevey, finally, in 1889, he took up his residence in Heidelberg.

After his departure from Dublin, the weak state of his eyes prevented Brünnow from engaging to any extent in scientific work, and thus he was enabled to give more time to music, of which he was very fond, and for which he possessed a remarkable talent. It is said that he once remarked, with quite too modest a view of his important contributions to astronomy, that he ought to have devoted himself entirely to music.

In March 1857 Brünnow married Rebecca Lloyd, daughter of Rev. Henry P. Tappan, at that time President of Ann Arbor University. Their only son, Rudolf Ernst, is now Professor of Oriental Languages at Heidelberg.

His death was quite unexpected. He had suffered for a long time from weakness of the heart, and was seriously ill in June of last year. He, however, partially recovered, and was making preparations for a journey into Switzerland when he was again taken ill, and died on August 20, 1891, in Heidelberg, at the age

of nearly seventy years. He was elected a Fellow of this Society May 14, 1869.

WILLIAM CHIMMO was born in the year 1828, and entered the Royal Navy in 1841, when only thirteen years old. He obtained the rank of lieutenant in 1850, and of commander in 1864. He served in the first and second China wars, against pirates in Borneo, and for six-and-a-half years was engaged in the *Herald* in the search for Sir John Franklin. Afterwards, as lieutenant of the *Iano*, he led the successful search for the lost expedition of Mr. Gregory and his party in Torres Straits, and assisted in the magnetic observations during the voyage of the *Royal Charter* to Australia. In command of the *Sea Gull* he was engaged in the survey of the west coast of Scotland, and as commander of the *Gannet* in the survey of Trinidad and the exploration of Labrador. He also explored the Sooloo Islands, where he had three officers and two men wounded in the attack upon a nest of pirates, of whom 190 were killed.

From 1856 to 1858 Captain Chimmo was secretary to the Hydrographer of the Admiralty. The greater portion of his life was devoted to the Hydrographic Survey, and he wrote several papers on the result of deep-sea soundings in the Atlantic, on which he was employed. His only communication to this Society was an account of the great shower of meteors on November 14, 1867, which he observed when surveying in the West Indies.

After his retirement from the Navy, with the rank of post-captain, in 1873, he settled at Weymouth, where he died, October 30, 1891, at the age of sixty-four. He was a Fellow of the Linnean, Royal Geographical, and Meteorological Societies. He was elected a Fellow of this Society on November 11, 1859.

ALBERT ESCOTT was born in Somersetshire in 1840, his father being a member of an old county family. His father died in 1845, and in 1851 the son entered the Royal Hospital School, Greenwich, as pupil in the Upper School, which at that time consisted of the sons of naval officers. The first years of his school life were passed under the care of the late Rev. Dr. Hill, and afterwards under that of Mr. John Riddle. In 1855 Mr. Escott was appointed senior pupil teacher in the Upper School, and after three years became assistant master in the Nautical School, and was afterwards second master in Section C. He was appointed head master in 1870, at which time the school was entirely reorganised. In 1874 an important change was made, naval schoolmasters being sent to be trained by Mr. Escott and his assistant at Greenwich, from which certificates were granted, instead of at the training colleges to which naval schoolmasters had been formerly sent. After the death of his former teacher, Mr. John Riddle, Mr. Escott edited the 8th edition of that

author's well-known treatise on Navigation. Mr. Escott was a Freemason, and took an active interest in the charitable institutions connected with that body, besides filling various parochial and other public offices. He was a man of marked ability and varied attainments, and by his personal qualities he won the affection and esteem of a wide circle of friends.

Mr. Escott died October 28, 1891. He was elected a Fellow of this Society May 13, 1864.

THOMAS HENRY HOVENDEN was born in Finsbury, November 4, 1833. He was educated privately, and on leaving school was articled to a solicitor. He was afterwards for many years the senior member of the firm of Hovenden, Heath & Berridge, surveyors, of Bishopsgate Street, from which he retired on account of failing health a few years before his death. Mr. Hovenden was a member of the British Archæological Association, and was elected a Fellow of this Society, December 12, 1884.

JOHN MERRIFIELD was born August 24, 1834, at Petertavy, on the borders of Dartmoor. He received his early education at the Tavistock National School, and after passing two years at the Exeter Training College was appointed elementary schoolmaster at Marytavy. His spare time was devoted to surveying and chemistry, and he was much sought after as an analyst. His natural love for mathematics, however, led him in 1862 to leave Marytavy for Plymouth, to become the founder and head master of the Plymouth Navigation School, thenceforward occupying himself in astronomy and kindred subjects.

In 1860 he published, in conjunction with Mr. Evers, a *Treatise on Navigation and Nautical Astronomy*. In 1876 he published a work on *Magnetism and the Deviation of the Compass*, and in 1887 a *Treatise on Nautical Astronomy*, in which he introduced his own method of clearing the lunar distances. In 1888 he received the Bronze Medal of the Falmouth Polytechnic Exhibition for an artificial horizon for sea use.

Mr. Merrifield's interest in education was shown by the science classes conducted by him, in most cases for the love of teaching, in which students were instructed in the elements of mathematics. He was a Fellow of the Royal Meteorological Society, and made and tabulated regular observations for nearly twenty-seven years. At the time of his death he was engaged in preparing for publication a work on *Climate and Health*.

Mr. Merrifield died June 27, 1891, having been in failing health for nearly two years. He was elected a Fellow of this Society February 10, 1865.

JESSE SCOFFIN NIMKEY was born in 1838. He was engaged in a business which demanded most of his time and attention, but

was an assiduous student of astronomy, especially during his later years. He had an observatory built for his 6-inch telescope, and employed his skill as an artist in making drawings of the Moon and planets. He constructed an ingenious model for illustrating and demonstrating the phenomena of the solar system, the longitude and right ascension of the Sun and Moon, right ascensions of stars, &c. The model was exhibited at the People's Palace in 1887.

Mr. Nimkey was a skilled musician, and was an organist in London for more than twenty-eight years. He died from a disorder brought on by over-work and study on December 17, 1891. He was elected a Fellow of this Society January 11, 1889.

Norman Robert Pogson was born on March 23, 1829, at Nottingham, where his father carried on an old-established business as a hosiery manufacturer. Being intended for a commercial career, young Pogson received only an ordinary education, but very early in life he evinced scientific tastes and a marked dislike of business. His desire for scientific information was encouraged by his mother, who procured him access for some time to the works of an optician and instrument maker at Nottingham. On the removal of his father to Manchester he succeeded in obtaining lessons in trigonometry and other branches of mathematics, and eventually Mr. Hind, sen., of Nottingham, suggested to his parents to send him to London, giving him a letter of introduction to his own son, Mr. J. R. Hind, at that time astronomer of Mr. Bishop's observatory in the Regent's Park. Here Mr. Pogson was enabled to study practical astronomy under excellent guidance, while he supported himself by giving lessons in mathematics. In 1847 he first introduced himself to the notice of the astronomical world by publishing parabolic elements of two comets, and in the following years he computed elements and ephemerides of various comets and minor planets. This led to his being engaged as an assistant at the Regent's Park Observatory, which post he only held for less than a year, as he was at the close of 1851 appointed assistant at the Radcliffe Observatory, Oxford. Here he was regularly employed in observations with the transit instrument from the beginning of 1852 to the end of 1858, but though he devoted himself with energy to the routine work required of him, he found time for other observations as well, and soon became distinguished in the two fields of work with which his name will always be associated—minor planets and variable stars. In 1852 he discovered the variability of *R. Cygni*, and in the course of years he found eighteen other variable stars, the last being *X. Capricorni*, found at Madras in 1865. In 1854 he picked up the planet *Amphitrite*, which had, however, been found by Mr. Marth the night before, but two years later he was more fortunate, when he discovered *Isis* (42), and, encouraged by this and by the Lalande Medal which it procured him, he found in 1857 two other planets, (43) and (46). In the mean-

time he had in 1854 been selected by the late Astronomer Royal as one of the observers in the pendulum experiments at Harton Colliery, near South Shields, for determining the mean density of the earth; but he continued to devote most of the time which he could spare from his official work to studies on variable stars and on the magnitudes of the minor planets. The number which he adopted as the ratio of light between each magnitude, 2·512, of which the logarithm is 0·4, became by degrees universally adopted.

By his discoveries and numerous contributions to the *Monthly Notices* and the *Astronomische Nachrichten*, Mr. Pogson had acquired considerable renown among astronomers, and when Dr. Lee, towards the end of 1858, wished to revive the activity of the Hartwell Observatory, the charge of which had become too onerous for himself and Admiral Smyth, owing to their advanced age, he felt that he could not do better than entrust his instruments to Mr. Pogson. A regular agreement was drawn up as to the future work of the observatory (which curious document may be read in the *Speculum Hartwellianum*), and on January 1, 1859, Mr. Pogson entered on his new duties. At Hartwell he continued his favourite studies, especially devoting his time to a great piece of work which he had already commenced at Oxford in 1853—viz., an atlas of variable stars. This gave for each telescopic variable a map of its vicinity, 80′ square (on a scale of three inches to a degree), containing all stars down to the twelfth magnitude, and giving the accurate magnitudes of a certain number of comparison stars. In February, 1860, he announced that nineteen of these maps were finished, and if he had remained at Hartwell or at some similar observatory, this valuable piece of work would doubtless long ago have been published. In October, 1860, he was, however, appointed Government Astronomer at Madras, in succession to Captain Jacob, and left England soon after.

When Mr. Pogson arrived at Madras in the beginning of 1861, the observatory had recently been provided with a transit-circle by Troughton and Simms, which had arrived just before Captain Jacob's departure. It was mounted and ready for work in the spring of 1862, when systematic observations were at once commenced by three native assistants. The objects selected for observation were the brighter stars down to the fifth magnitude, the Moon and Moon-culminating stars, *Mars*, and the brighter of the minor planets, but particularly all known variable stars, and as many stars as possible south of 120° N.P.D., down to the ninth magnitude. From 1862 to 1887 more than 50,000 observations of fixed stars were made, but it was not till the last-mentioned year that Mr. Pogson was able to overcome the difficulties which up to then had prevented him from publishing any of the results of the observations. He then commenced the publication of annual catalogues of individual results and mean positions for each star, but he only lived to give three

volumes to the public, embracing the years 1862 to 1870. In addition to the unpublished parts of this work there are still awaiting publication: a catalogue of 2,200 stars for 1855, from observations made from 1853 to 1858 under Captain Jacob and Major Worster, as well as a number of miscellaneous observations made before 1860; also all the observations of minor planets, comets, occultations, and light-comparisons of variable stars. The only astronomical publication issued from the Madras Observatory under the direction of Mr. Pogson, in addition to the three volumes already mentioned, is the account of the telegraphic determination of the difference of longitude between Madras and eight other stations.

The disappointment which Mr. Pogson must have felt at having to wait for so many years before being enabled to publish his meridian work was not the hardest one which he had to bear. When he first commenced work at Madras he expected that a European and scientifically-trained first assistant would very soon be appointed, and he had planned a continuation of Argelander's *Durchmusterung* in the southern hemisphere, and the subsequent observation on the meridian of the stars thus mapped. All these hopes he was destined to see dashed to the ground within a few years of his arrival in India. But this did not prevent him from continuing his former work, and he went on searching for minor planets, of which he at Madras found five and re-discovered the lost *Freia.* The name which Pogson had acquired as a skilful observer caused Klinkerfues in 1872 to address his well-known suggestion to look for the lost comet of *Biela*, near θ *Centauri*, to the astronomer at Madras, who readily acted on the suggestion and found a small comet not far from the spot indicated. But his favourites, the variable stars, were not forgotten; he added seven new ones to those already known, and continued to work on his Atlas of variable stars during the years of his residence in India. The difficulties connected with the observations required for this work, which could only be carried on during the absence of the Moon, have unfortunately prevented this Atlas from being completed; and here again we cannot help regretting that Mr. Pogson was drawn away from the class of work to which he felt specially inclined, and left to struggle without proper assistance against an overwhelming amount of routine work, including magnetic and meteorological observations, with plenty of arrears to be worked up.

Mr. Pogson was created a Companion of the Indian Empire on January 1, 1878.

During the thirty years which Mr. Pogson spent in India he never took any holidays. Even when very far from well, about six months before he died, he was indefatigably active in dismounting and cleaning three of the principal instruments, and in May last, though seriously ill, he had a look at *Mercury* on the Sun's disc with an old $3\frac{1}{2}$-inch refractor from Hartwell. He

died on June 23, 1891, leaving a large family by his first marriage, and a widow and two young children. He was elected a Fellow of this Society on May 11, 1860. J. L. E. D.

HENRY PRATT was born in Brighton on March 29, 1838, and was the eldest son of Mr. Henry Pratt, a naturalist and taxidermist of the same town. The son was almost entirely self-educated, but owed much to two years' instruction under Mr. Strugnell, of Christ Church School, Brighton, who helped to inculcate the love of study and to form the orderly habits of thought which Mr. Pratt showed in after years. By profession he was a watchmaker, and was esteemed for his ingenuity in works of mechanism and the skill which he could command in delicate workmanship. Astronomy, however, was his favourite pursuit, though all his studies in this direction had to be conducted at the close of a hard day's work in his business.

The instrument which he employed was a With-Browning reflector, with an excellent mirror of 8·15 inches aperture. He had a keen sight, and was a skilled draughtsman. These advantages, combined with indefatigable industry, enabled him to do much useful work, and he soon became known as an astronomer far beyond the limits of his native town.

During the partial solar eclipse of 1873 May 27, he was fortunate in obtaining observations of a portion of the Moon's limb beyond the disc of the Sun. In his first contribution to the *Monthly Notices* (vol. xxxiii. p. 577) he gave an account of his observation of this interesting phenomenon; the Moon's limb was seen to a distance of about 5 minutes of arc beyond the Sun's disc, of course projected upon the solar corona. The instruments were repeatedly changed, and it appears certain that the phenomena observed were not of instrumental origin.

Mr. Pratt was an assiduous observer of the lunar surface, and especially of the delicate markings and minute craterlets upon the floor of *Plato*, which he carefully studied. In 1877 he communicated to the Society some short but suggestive notes on *Mars*, accompanied by drawings which are preserved in the library. In 1880 he published a careful determination of the rotation period of *Jupiter*, which involved the observation of 321 rotations of the planet, and he showed reason for considering that the generally accepted rotation period was somewhat too short. In vol. xliv. of the *Monthly Notices* he gave the results of a series of observations of *Saturn*, accompanied by a fine drawing of the planet, and he appears to have obtained satisfactory observations of the innermost satellites, and of the fine division of the rings. In the same volume he published his observations of the *Merope* nebula in the *Pleiades*, which he was well able to see with his reflector, using a low-power Kellner eyepiece; with a slotted diaphragm to conceal the bright stars he even succeeded in seeing the faint patch of nebulosity

between *Merope* and *Alcyone*, first detected by Dr. Common with the 36-inch reflector.

Mr. Pratt was also a contributor to the *Astronomical Register* and other journals, and supplied regular weather reports to a local newspaper.

In August, 1890, his health having broken down, he decided, on the recommendation of his medical adviser, to leave Brighton and settle at Crowborough, Sussex. This intention he was never able to carry out, as his strength gradually failed, and on March 7, 1891, he died at Brighton, in the fifty-third year of his age.

He was elected a Fellow of this Society on April 12, 1872.

Edward Williams Snell was born at Maker, Cornwall, in the year 1834. At the age of eighteen he went to Dr. Burney's School at Gosport, where he prepared pupils for the Army and Navy; and in 1859 he became mathematical master at the Royal Hospital School, Greenwich, from which post he retired in 1870. For the last eighteen years of his life he was conductor of a private school at Blackheath, where, owing to his untiring energy and the help he was always ready to give his pupils, he was particularly successful in preparing them for examinations, and gained their lasting affection. Mr. Snell had only just retired from work when he was attacked by a painful illness, which caused his death July 7, 1891, at the age of fifty-seven. He was elected a Fellow of this Society March 10, 1871.

Eduard Schönfeld* was born at Hildburghausen, in the Duchy of Meiningen, on December 22, 1828. His mother taught him to read, and he appears to have taught himself the rudiments of arithmetic. Later on, when he went to the Gymnasium of his native town, he could give assistance to the pupils of the highest classes in mathematics. Following the usual curriculum of the school, he remained two years in the senior class before attaining the legal age for the final examination. On leaving the Gymnasium, young Schönfeld expressed his desire to study astronomy, but abandoned the idea at the time, at the wish of his father, who considered it a profession without prospects, and, by the advice of his uncle, he studied architecture, first at the Polytechnical School at Hanover, and then at Cassel.

In the spring of 1849 he worked in the chemical laboratory at Marburg under Bunsen, but his former love for astronomy was revived by Gerling's lectures, and, making it his sole study, he translated the first book of the *Mécanique Céleste* and the *Theoria Motus* during his residence at Marburg. His first astronomical observation was an occultation of γ *Arietis*, made on November 29, 1849. In 1851 Schönfeld availed himself of an opportunity to visit the Bonn Observatory, and the charm of

* Abridged from an article by Prof. Krueger in *Vierteljahrsschrift*, Jahrgang xxvi., Heft. 3.

Argelander's personality was so great that on his return to Marburg he wrote to him of his great desire to study at Bonn. Argelander received the proposition most warmly, and at Easter, 1852, Schönfeld matriculated at Bonn, and attended Argelander's lectures. He also observed diligently, and took part in reductions of observations of newly-discovered planets and comets. Argelander had such confidence in Schönfeld's ability that he appointed him to a vacant assistantship, though he had not yet taken his degree. In the following year, 1854, Schönfeld won his doctorate with distinction by his treatise *Nova Elementa Thetidis*.

We now come to an important event in Schönfeld's life—viz., his connection with the Bonn Survey of the Northern Heavens, in the successful completion of which he had so great a share, even after he had left the Bonn Observatory. In the accuracy of his observations and scrutiny of the results he vied with his great master, and he never lost courage, even when the strain of observing throughout the night and reducing the results in the day became almost too severe. After the Bonn Survey Schönfeld turned his attention to the light-changes in variable stars, a problem that was at that time exciting the interest of astronomers, owing to the discovery of new stars and the observations of Argelander. Schönfeld availed himself of Argelander's simple and trustworthy methods, and the evenings which could not be utilised for zone work, on account of moonlight, were employed in making as complete observations as possible of the minima of *Algol* and *S Cancri*. Schönfeld now became a Privat-Docent in the University, but did not long exercise this function, for in 1859 he was appointed Director of the Mannheim Observatory, through the influence of Eigenlohr, who applied to his friend Argelander for advice. The Mannheim Observatory must have seemed antiquated when compared with the convenient and perfectly-arranged observatory at Bonn. From its position and construction it was almost impossible to mount satisfactorily even a single instrument that would be capable of good work, and Schönfeld had to be contented with a small parallactic refractor of Steinheil's of 73 lines aperture. His chief work with this instrument was on nebulæ and variable stars; he also observed comets and new planets with regularity. With regard to nebular work, Schönfeld chose the objects to be observed, with few exceptions, from Herschel's Catalogue, on the ground that these could be sufficiently well observed with his refractor. He connected the nebulæ with the neighbouring stars by successive ringmicrometer determinations. Four hundred and eighty-nine observations of nebulæ by Schönfeld are collected in two volumes of the publications of the Mannheim Observatory, published in 1862 and 1875 respectively. His researches on variable stars are published in two catalogues in the *Jahresberichte* of the Mannheim Physical Society, Nos. 32 and 39, dated respectively 1866 and 1875. The first catalogue

comprised 119 stars, the second 143, for which the variability had been ascertained.

Schönfeld was a member of the Astronomische Gesellschaft from its foundation in 1863, and from 1863 to 1869 was a member of the Council, but without any special office. In 1875, in conjunction with Winnecke, he undertook the duties of Secretary of the Society and Editor of its publications, and also the preparation of the ephemerides of variable stars.

On the death of his master and life-long friend, Argelander, which occurred on February 17, 1875, Schönfeld was appointed Director of the Bonn Observatory and Professor in the University.

Shortly after entering on his new office he began preparations for an extensive work—the greatest and last of his life—i.e., the extension of the Survey of the Heavens to 23° South Declination. The experience gained in the Northern Survey gave opportunity for the introduction of newer and more convenient methods. Schönfeld determined to use a more powerful telescope—one of Schröder's refractors of 70 lines aperture. The use of a higher magnifying power necessitated a smaller field of view, and consequently narrower zones and a greater number of them; but the gain in accuracy of position was important, as well as the diminution of the danger of omitting stars in a rich field. Schönfeld himself superintended both observations and revision. From 1875 to 1881 610 zones were observed, and by February, 1884, 16 zones more were added, which, with the preceding zones, comprised 700 hours in Right Ascension. These observations furnished 363,932 single-star places as basis of a catalogue of 133,659 stars, which is published in vol. viii. of the *Bonn Observations*.

It is perhaps to be regretted that the Northern Survey had not been carried out in the same manner—i.e., with smaller zones and a more powerful telescope, an illuminated field, and, as far as possible, the same observer. But it was scarcely to be expected that one and the same observer should persevere through long years at the same work. All praise is due to Schönfeld, who attempted this survey, and carried it out in its smallest details. He was an extremely hard worker. It often happened during long periods that he remained almost uninterruptedly at his work from nine in the morning till three at night. Yet to him his work never seemed to progress fast enough. The 8th volume of the *Bonn Observations* appeared in 1886—in spite of the most strenuous exertions he could not publish it sooner.

His strong sense of duty and his learning, as profound as that of the greatest astronomer of our time, procured for Schönfeld a pre-eminent position among his colleagues at the University, and his benevolent and unassuming character gained him many friends. Through the Astronomische Gesellschaft he was brought into friendly relations with both old and young colleagues in his profession. He took part in the twenty-fifth

anniversary of the Pulkowa Observatory, and seized the opportunity of making the acquaintance of the astronomers there. In 1887 he attended the first Paris Congress for the photographic chart of the Heavens, and took part in the discussions. In 1889 he again went to Pulkowa, on behalf of the Prussian Minister of Education, to convey the congratulations of the German astronomers on the occasion of its Jubilee. Schönfeld was not permitted by his doctor to attend the meeting of the Gesellschaft, held at Brussels in the same year. To this meeting was sent to him from America the Watson Medal—a mark of esteem that he valued most highly. In 1891 it became apparent that Schönfeld was seriously ill, and on May 1 he died, after protracted suffering. He was elected a Foreign Associate of this Society November 8, 1878.

Proceedings of Observatories.

The following reports of the proceedings of observatories during the past year have been received from the Directors of the several observatories, who are alone responsible for the same:—

Royal Observatory, Greenwich.

The number of meridian observations made during the year 1891 was not so large as usual, owing to the fact that the transit-circle was under repair by Messrs. Troughton and Simms from August 10 to October 7, during which time the object-glass was repolished, and the micrometer screws and wire system of the eye end were renewed. The total number of transits observed was 4,731, and of zenith distances 4,433; and there will be 1,813 stars in the annual catalogue. The observations of clock stars and close circumpolars made during the years 1887–1891 are to be collected in a Five-year Catalogue of fundamental stars, which will give more recent determinations, for use in the *Nautical Almanac* and in the reduction of the Greenwich observations, than the general catalogues necessarily published at longer intervals.

The results of the preliminary observations for determining the dependence of personal equation on stellar magnitude were communicated to the Society in June last.

The mean error in R.A. of Hansen's Lunar Tables, with Newcomb's corrections, as deduced from eighty-four observations with the transit-circle in 1891, is $+0^s\cdot079$, a larger quantity than any for previous years since 1883. If we allow for the absence of observations in August and September, when the error has in previous years been greater than the mean, we must further increase this quantity.

Only one observation of horizontal flexure of the transit-circle was made in 1891, on May 4, the result being $+0''\cdot06$. The apparent correction to nadir observation, deduced from reflexion observations of north and south stars, is $+0''\cdot071$.

The results of the observations of thermometers, placed at different points of the transit-circle room, for the years 1888–1891, have been communicated to the Society. It appears that the distribution of temperature may affect the R−D correction,

and future experiments will be arranged more directly with the object of elucidating this point.

With the altazimuth the Moon has been regularly observed in the first and last quarters as before. On the occasion of the solar eclipse of June 6, Mr. Crommelin made an altazimuth observation of the Moon's dark limb. The instrument was also occasionally used for time determinations when the transit-circle was under repair.

Comet *b* 1891 (Wolf) has been observed with the Sheepshanks equatoreal on seven nights.

Five disappearances and six reappearances of stars occulted by the Moon have been observed, and forty-two phenomena of *Jupiter's* satellites. The observations of the solar eclipse on June 6 have been communicated to the Society.

Preparations were made for observing the transit of *Mercury* on May 10, and occultations of stars on the occasion of the lunar eclipse of November 15, but bad weather prevented any results being obtained.

The work with the 13-inch photographic telescope during the past year has been chiefly preliminary and experimental, several important questions having to be settled before the regular work of the photographic chart could be advantageously commenced. In all 204 photographs have been obtained during the year, the total number of exposures being about 830. These have been taken mainly with a view to determining the relation between diameter of image, duration of exposure, and brightness of star, and the results of this investigation have been recently communicated to the Society.

Besides this a considerable time has been spent in examining the effect of placing various screens before the object-glass, an investigation rendered necessary by a resolution of the Permanent Committee at their last meeting. Forty-five plates, containing 108 exposures, were taken with screens. Numerous photographs of trails of stars have also been taken to test the orientation, and from a discussion of these it appears that the line of collimation of the telescope is sensibly inclined to the polar axis at an angle of about 30′, the orientation for 65° N. Dec. differing by about 20′ from that for the equator. It has been found that the *réseaux* originally supplied decompose somewhat rapidly, and those which have been in use eighteen months are now seriously defective. A new *réseau* has been obtained from M. Gautier recently.

As regards the selection of guiding stars for the photographic chart, the catalogue of places (epoch 1900·0) for the Greenwich zones +65° to +80° is complete, the reductions for zones +80° to the pole being deferred. The catalogue for zones +60° to +62° of the 60°−65° zone to be photographed at Rome has been sent to Father Denza, and the rest is nearly finished. The first twelve hours of R.A. of the Oxford zones +25° to +29° have been sent to Oxford, and the other half

is nearly complete. A considerable amount of work has been done on the San Fernando zones (− 3° to − 5°). The stars have all been selected for this zone, and the places for epoch 1900 have been computed for those between R.A. 12^h and 18^h.

The 12¾-inch telescope of the S.E. equatoreal was dismounted last November in preparation for the mounting of the new 28-inch object-glass, on which Sir H. Grubb is now engaged. The new 36-foot dome, to house the large telescope, described in the *Monthly Notices* for last May, is in course of construction by Messrs. T. Cooke & Sons, but the work has not advanced as rapidly as was hoped, and the dome is not yet ready for erection.

The regular series of observations of the displacement of lines in stellar spectra for the determination of their motion in the line of sight has not been continued during the past year, but as a preliminary discussion of the results obtained in former years appeared to show that they were affected to some extent by the position of the spectroscope, *Vega* and *Altair* were observed during the summer and autumn at as wide a range of hour-angle as possible, and with the spectroscope set to each of the four positions 0°, 90°, 180°, and 270°; the slit being parallel to the declination circle at 0°. The numbers of observations obtained of *Vega* are: at 0°, 39; at 90°, 42; at 180°, 36; and at 270°, 39; and of *Altair*: at 0°, 30; at 90°, 32; at 180°, 26; and at 270°, 29. The measures are now under discussion, but give clear indications of the existence of the systematic error referred to. The dismounting of the 12¾-inch equatoreal in order to prepare for the mounting of the new 28-inch telescope in its place was commenced on November 19, and further observations with the spectroscope were necessarily discontinued.

Photographs of the Sun have been taken with the Dallmeyer 4-inch photoheliograph on 224 days, and of these 525 have been selected for preservation, including sixteen photographs with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination. Owing to the interference of the new Museum building in the south ground the Dallmeyer photoheliograph was removed on September 9 from its old position in the wooden dome south of the Photographic Offices, and was erected temporarily on the first floor of the new Museum. From this position it is possible to photograph the Sun for about two hours each day, except during the height of summer. A 9-inch photographic telescope by Grubb, presented to the observatory by Sir Henry Thompson, has been mounted on the Lassell equatoreal for use as a photoheliograph, and has been fitted with an enlarging camera to give 8-inch pictures of the Sun, and with a specially contrived exposing slit, made of aluminium, with which a very rapid exposure can be given. Photographs of the Sun have been taken with the Thompson photoheliograph on fifteen days, from November 10 to the end of the year. Photographs have also been received from India and Mauritius up to 1891 November 30; leaving

fourteen days in the year ending on that date for which no photograph is yet available for measurement.

The revival in the solar activity has been exceedingly marked during 1891. Whilst in 1890 there were no fewer than 173 days without spots, there were only 21 in 1891, and these all occurred during the first three months of the year; there have been no days without spots in 1891 since March 29. Many of the spot-groups have been very large and complicated, the one which first appeared on August 28 being especially noteworthy as the largest since June 1885.

Arrangements have been made with Professor McLeod, of the McGill College Observatory, Montreal, to determine the longitude of Montreal from Greenwich, and at the same time those of the cable termini, Canso in Nova Scotia, and Waterville, county Kerry. It was originally intended to commence the work in August 1891, but it was found impossible to get the requisite transit instruments, apparatus, and other preparations for four stations completed in time, and the commencement has been deferred till April 1892. It is proposed to divide the operations into two parts, separated by an interval of some two or three months in the summer, to detect or eliminate any possible systematic error depending on the season of the year. In the interval it has been arranged with the French Service Géographique to re-determine the longitude of Paris, as mentioned in the last report. For use in these and other longitude operations a permanent transit pavilion has been erected in place of the wooden hut set up in 1888. This building has been specially designed in the Department of the Director of Works to the Admiralty, with a roof consisting of a pair of semi-domes sliding apart so as to give a clear opening of 2 feet 6 inches, and avoid abnormal refraction by its circular form.

To provide additional accommodation for chronometers, a south wing to the new octagonal Museum is to be built in the present year, this wing forming part of a larger scheme for a cruciform building to accommodate the physical branch of the Observatory. A proposal is under the consideration of the Admiralty for an electric-light installation, the gas-engine, dynamo, and storage batteries being placed at the south end of the observatory enclosure, as far as practicable from the magnetic observatory.

The volume of Greenwich Observations for 1889 was passed for press in August last, and has been distributed. The volume for 1890 is well advanced.

The Treasury having authorised the addition of two assistants to the staff, Mr. Crommelin was appointed last May as the additional second-class assistant, and Mr. Lewis has been promoted to be the additional first-class assistant. It may also be mentioned that Mr. Downing has been appointed Superintendent of the *Nautical Almanac*, Mr. Thackeray being promoted to the vacancy in the first-class thus occasioned. There are thus

vacancies for two second-class assistants, which have been filled up quite recently by the appointment of Mr. W. W. Bryant and Mr. T. C. Hudson.

Royal Observatory, Edinburgh.

During the past year Mr. Thomas Heath has continued to make out the weather returns for the Registrar-General for Scotland, besides distributing the time and taking the meteorological readings. Mr. Heath has also made preparations for comparing the individual star-places of the Edinburgh observations with the Fundamental Catalogue of the *Astronomische Gesellschaft.* Already the 519 stars of Auwers' Catalogue which occur in the Edinburgh volumes have been reduced, with the proper motions of the *Astronomische Gesellschaft* Catalogue, to the years in which observations have been made. Within the year Nos. 13 to 21 of the Edinburgh Circulars have been distributed. For various detailed ephemerides of comets observers are again indebted to Herr A. Berberich, of the Berlin Recheninstitut.

The site of the new observatory has been enclosed by a light wire fence, the buildings staked out, and the foundations partly cleared. The pipes for water-supply and drainage are being laid and a pumping-chamber is also in progress. The final specifications of the observatories and dwellings are now drawn out and printed. It is expected that invitations for tenders will appear within a few days.

At Dunecht the packing of a number of the smaller instruments, and, later on, of the more delicate parts of the transit-circle, has been personally superintended by Dr. L. Becker.

Early in the year Dr. Becker undertook the reduction of the meridian observations of nebulæ mentioned in former reports. Advantage was taken of visits to Dunecht in March and May to supplement the work already done by 172 further observations. The whole of the materials were afterwards combined and compared with the results obtained by previous workers in the same field. Details of this investigation, together with a catalogue of the places of 217 nebulæ, will shortly be printed.

A paper, also by Dr. Becker, on the latitude of Dunecht as found by transits in the prime vertical, is also ready for the press.

The Makdougall-Brisbane prize of the Royal Society of Edinburgh has been awarded to Dr. Becker for his paper on "The Solar Spectrum at medium and low altitudes," of which some account was given in last year's Report.

In July Professor Copeland communicated a paper, "On the bright streaks on the Moon," to the Royal Society of Edinburgh, which will appear in their Transactions. It was illustrated by a model of the Moon, the streaks on which are produced by a coating of minute glass spherules, these having the property of

throwing back the light when illuminated from the front, while under other conditions they are scarcely visible. The remarkable property possessed by the lunar streaks of becoming conspicuously visible only near full Moon is thus shown by the streaks on the model. Photometric measures of the model under various illuminations yielded a phase-curve analogous to that derived by Zöllner from his own and Sir J. Herschel's observations of the brightness of the Moon.

Royal Observatory, Cape of Good Hope.

Observations with the transit-circle have been continued regularly throughout the year 1891. The principal objects of observation have been the Sun, *Mercury*, *Venus*, stars for a Ten-year Catalogue for 1890, stars occulted by the Moon, stars employed for latitude determinations in the Geodetic Survey of South Africa, comet comparison stars, and stars employed in zones for determining the scale value of the heliometer.

The work accomplished with the transit-circle in 1891 has been as follows:—

	R.A.	N.P.D.
No. of observations of ⊙ (both limbs)...	92	92
" " Mercury...	40	40
" " Venus	76	76
" " Azimuth stars	534	...
" " Catalogue stars	5470	6776
" " Stars for personal equation ...	336	...
Total	6548	6984

in addition to

509	determinations	of	Run.
50	"	"	Flexure.
110	"	"	Collimation.
514	"	"	Level.
509	"	"	Nadir.

The weather has been very unfavourable for observing during the latter half of the year; the heavy "South-Easters," with the unsatisfactory conditions of definition accompanying them, set in at a much earlier date than usual. Thus, during the last four months of the year, there were only twenty-five nights on which really satisfactory observations could be made.

The Zenith Telescope.—Since the completion of the first series of observations (mentioned in last year's report) the zenith telescope has been dismounted and thoroughly overhauled. The definition has been greatly improved by a new prism; two levels have been introduced, instead of one, for measuring the change

in the zenith distance of the optical axis in the two positions of the instrument. A self-registering micrometer has also been added, and several mechanical defects remedied. The efficiency of the instrument seems to be greatly enhanced by these improvements, which have been carried out by Messrs. Repsold. From 1892 February 1, the instrument will be devoted to a determination of the Constant of Aberration by methods independent of variation of the latitude, but including its determination.

The occultations during the total eclipse of the Moon on November 15, which were predicted for many observatories by Dr. Döllen, were observed at his request as follows:—

Observer.	Instrument.	No. of Phenomena.
Gill	10-inch guiding telescope of the photographic equatoreal	12
Finlay	7-inch Merz	8
Pett	6-inch Grubb	4
Cox	7-inch Heliometer	5

Full particulars have been communicated to the Society. This observatory is at great disadvantage in the observation of such phenomena, owing to the want of a larger telescope.

In addition to the above, the following occultations were observed during the year:—

Disappearances at the dark limb	17
Reappearances " "	7
Reappearances at the bright limb	1
	25

The reappearance at the bright limb was that of σ *Sagittarii* on November 6. Some of these phenomena were observed by two or more observers. The figures given are the number of phenomena successfully observed, not the number of observations by different observers.

Only a very limited number of comet observations have been made, viz.:—

Comet Barnard-Denning...	3 nights.
Comet 1891 *e*	1 night.

With the heliometer, 219 measures of the mutual distances of *Jupiter's* satellites, and the same number of position-angles have been made in response to Dr. Elkin's request for co-operation with Yale, for a determination of the mass of *Jupiter*, and the correction of the orbits of the satellites. Observations have been made on forty-one nights for the parallax of β *Orionis*, ϵ *Orionis*, α *Eridani*, β *Crucis*, α *Piscis Australis*, τ *Ceti*, and α *Crucis*. The exceptionally bad definition during the last four

months has greatly limited the output of refined heliometer work—indeed, for three successive weeks of nearly clear sky it was impossible to make a single satisfactory observation of *Jupiter's* satellites, so agitated and *woolly* were the images.

H.M. Astronomer went to Europe in February for the purpose of attending the *réunion* of the Permanent Committee of the Astrophotographic Congress at Paris. Advantage of this opportunity was taken to return the object-glass of the photographic telescope to Sir Howard Grubb for correction of the optical imperfection mentioned in the last report. Sir Howard Grubb found a serious error in the figure of the outer surface of the crown lens, which he is certain did not exist at the time he applied his previous final tests. The defective surface has been reground and refigured, and, thanks to the kindness of Professor Pritchard, the object-glass was tested at Oxford, under his supervision, by Mr. Plummer. The instrument now gives good photographic images.

Some delay has been caused in the prosecution of the chart work by the non-arrival of photographic plates; they have now (January 12) just come to hand.

The work done with the photographic telescope has been:—

Iris comparison stars	21	exposures.
Victoria comparison stars	75	"
Focussing and testing	112	"
Screen experiments...	16	"
Jupiter	270	"

The *Jupiter* exposures extended over forty-four nights, and were made for the purpose of determining the relative coordinates of the satellites in connection with the work undertaken in co-operation with Dr. Elkin. Each plate has also 2 exposures on a pair of standard stars near *Jupiter*, the position-angle and distance of which have been determined with the heliometer. These standard stars will serve to determine the scale value and the orientation of the plate.

A great deal of labour has been bestowed on the determination of the errors of the scales of the photographic measuring apparatus and on the errors of *réseaux*. Some account of a portion of this work has been sent to Professor Pritchard. A large number of plates of the *Victoria* stars and of *Jupiter's* satellites have been measured.

Professor Auwers has completed his discussion of the 5,300 meridian observations of the *Victoria* comparison stars (made at 22 different observatories), and has communicated the results. The whole of the heliometer observations of the triangulation made at the Cape and Göttingen have been reduced at the Cape, those made at Yale have been communicated by Dr. Elkin, corrected for refraction, aberration, &c. The heliometer measures

of distance have been completely discussed and reduced to a common system, and then compared with the corresponding distances computed from the meridian observations.

For the determination of the 74 unknown quantities (viz. $\Delta\alpha$ and $\Delta\delta$ for each of the thirty-seven stars) the heliometer distances afford 175 equations, the position-angles 26 equations, and the meridian observations 74 equations. These equations are now formed, and their solution is only deferred pending a reply from Professor Auwers to sundry questions respecting details of his discussion of the meridian observations, as these details affect the weights of the equations.

The reductions of the meridian work, so long in arrear, have been rapidly pushed forward since the increase of the available computing force, sanctioned by the Lords Commissioners of the Admiralty. The reductions to apparent place are completed to the end of 1891, the examination of the Right Ascensions to the same date, and that of the North Polar Distances to the middle of September. One copy of the corrections to mean place is finished to the end of July 1891, the duplicate to September 1890.

The publication of the catalogue for 1885, otherwise complete, is only delayed on account of the necessity for a re-discussion of the N.P.D.'s in the light of recent investigations connected with change of latitude.

The results of the Cape Meridian observations of the Sun, *Mercury*, and *Venus*, to the end of 1890, have been communicated to Professor Simon Newcomb, for incorporation in the discussion of the constants of his new planetary tables.

The field work of the Geodetic Survey makes rapid progress. Major Morris, R.E., has completed the measurement of a meridian arc from Port Elizabeth to Kimberley, and H.M. Astronomer and Mr. Finlay have successively taken part in the measurement of a base line at Kimberley. Major Morris has completed the connection of this chain of triangles with the Kimberley base line, and is now engaged on a longitude chain of triangles connecting the Kimberley arc with Maclear's arc along the parallel of 31° south latitude. This arc, with a short latitude arc connecting the last-mentioned longitude arc (the Hanover longitude arc), at its middle point, with the longitude chain which connects Port Elizabeth with the southern triangles of Maclear's arc, will complete the field work of the Geodetic Survey of the Cape Colony and Natal. It is expected that this work will be finished by the end of August 1892, when immediate steps will be taken for its reduction and publication.

The meteorological observations made in the year 1890, at the observatory, have been printed, together with those taken in different parts of the colony, in the Report of the Meteorological Commission.

During 1891 thirty-six plates of the photographic *Durchmusterung* have been rephotographed.

Professor Kapteyn reports, under date 1891 November 8, with reference to his measurement of the plates of the Cape Photographic *Durchmusterung*, that about one hundred plates, including the last replicas, remain to be measured. The unexpected delay in completing the measures has been caused by the extreme richness of the regions, $-34°$ to $-57°$. The actual work accomplished is as follows:—

From R.A. 19^h to 7^h all is complete except the zone $-53°$ to $-58°$.

R.A. 7^h to 19^h all is complete except the zones

$$\delta - 53^{\circ} \text{ to } -58^{\circ}$$
$$-43 \text{ to } -48$$
$$-34 \text{ to } -38$$

The total number of observations made up to the present time is about 750,000, without taking account of 86,000 made on the zones $-34°$ to $-57°$, which were rephotographed and the original plates rejected. The two zones $-38°$ to $-42°$ and $-48°$ to $-52°$ have alone involved 265,000 observations. Up to the present time the work furnishes in all places for about 280,000 separate stars. The whole work will contain more star places than Argelander's *Durchmusterung* of the northern heavens, and will involve more than one million observations.

Armagh Observatory.

During the past year the 10-inch refractor has again been chiefly used for micrometric measures of nebulæ and neighbouring stars which have been observed on the meridian. The objects under observation are principally those of Schönfeld's second catalogue, which have not hitherto been observed with filar micrometers, while a limited number of objects have been entered on the working list in order to determine the personal equation between the Armagh results and previous measures. Owing to climatic difficulties, moonlight nights, and the long summer twilight, work of this kind can only progress very slowly.

In the autumn physical observations of *Jupiter* were made, particularly of the black spots in the northern hemisphere and of the new red spot.

The weather was very unfavourable on the night of the lunar eclipse of November 15, and only two occultations of faint stars were observed.

Cambridge Observatory.

The acquisition of the great refractor, the munificent gift of the late Mr. Newall, of Gateshead, will render this year memorable in the annals of the Cambridge Observatory.

Mr. H. F. Newall, M.A., Trinity College, son of the donor of the telescope, has enhanced the value of the gift by a large contribution to the expenses of removal, by himself superintending the re-erection, and by undertaking to work the instrument for five years.

The entire dome and mounting have been transported from Ferndene and erected in the field adjoining the Northumberland equatoreal. A spectroscope is to be provided from a grant which was made from "the Bruce Fund," through Professor E. C. Pickering. Sir H. Grubb is about to undertake some alterations to the driving clock. In the meantime some general investigations of the capacity of the instrument have been carried out, so far as the absence of clock-work will allow. A systematic series of photographs of the Moon have been taken with very short exposures, and the results show that a very fair image may be got on an ordinary sensitive plate set, roughly speaking, ¼ inch away from the visual focus, the focal length of the telescope being slightly under 29 feet. Preliminary measures have been taken by Vogel's spectroscopic method of the achromaticity of the object-glass, with very promising results.

About the usual amount of work has been done with the meridian-circle, except in the case of the zone stars, comparatively few of which required re-observing. The reduction of these observations, as far as Apparent Right Ascension and North Polar Distance, has been brought up nearly to date.

Wolf's periodic comet has been observed with the Northumberland telescope and square-bar micrometer on twenty-two nights, on which were obtained 147 comparisons with adjoining stars. Some of these stars require re-observing with the meridian-circle before their places can be relied on.

Several demands from other observatories, for places of stars included in our zone, have been met with promptitude; by far the largest of these was one made by the Astronomer Royal; in response the places of 791 stars, deduced from 2,819 observations, were furnished to him for the reduction of photographic zones.

The necessary preparations were made for observing the transit of *Mercury* on May 10, and the occultation of small stars during the total eclipse of the Moon on November 15. No observations, however, were made on account of the bad state of the weather.

The heaviest part of the work during the year has been the task of cataloguing the zone stars. The mean places for 1875·0 from each individual observation, to the number of 17,743, are already entered. This brings up the catalogue to the end of the

first eleven hours of Right Ascension. Another catalogue is also in course of preparation, which will give the place of each star deduced from the mean of all the observations of that star given in the larger catalogue; this has been done for the first two hours of Right Ascension.

A new volume of the observations is going through the press.

Dunsink Observatory.

The photographic work at this observatory with the 15-inch photo-reflector which was in progress at the beginning of last year was interrupted early in January for the purpose of altering the form of the clock, as explained in last year's report.

It was hoped by taking the motion direct from the spindle to obtain running sufficiently accurate for photographic work, and at the same time one of Grubb's electric slow motions in R.A. was applied. In this form, however, it was found that the clock was not powerful enough to drive the instrument when the accelerating key was down, and having tried an auxiliary weight, so arranged as almost to overcome the friction in the bearings of the polar axis—an arrangement which proved unsatisfactory—it was found necessary to increase the driving weight of the clock to nearly 200 lbs.

With this weight the running of the clock is very much improved, and there does not appear to be any periodic irregularity in the gear which connects the clock with the polar axis; but there are still occasional irregularities which necessitate uninterrupted watching, and render an exposure of even a quarter of an hour a very laborious task. It is possible, however, by close attention during the whole time of exposure, and in consequence of the beautifully smooth action of the slow motion in R.A., to obtain star images which, under the magnifying power employed in the microscope, appear sensibly circular.

In September the examination of the microscope supplied by Messrs. Troughton & Simms for measuring the photographs was commenced. This instrument is similar to the microscope supplied by the same firm for the Oxford University Observatory, except that the frame for holding the plate, which in the Oxford University instrument carries a 2-inch circular, is in our case adapted for a 3½-inch square plate.

The screws of this instrument were examined in the usual way for periodic error and for differences of screw-value at different parts of the screw, and appear satisfactory, although in both respects the (H) horizontal screw is superior to the (V) vertical screw. In the case of the H screw the differences of screw-value are quite inconsiderable, except for a small part near the end of its range, where the error from this cause runs up to nearly half a second. The periodic errors are very small, and are represented by the formulæ—

$$+0''.048 \cos (u - 52^\circ\ 58') - 0''.030 \cos (2u - 28^\circ\ 28')$$

and

$$-0.161 \cos (u - 56\ 25) - 0.031 \cos (2u - 43\ 19)$$

for the H and V screws respectively.

In consequence of the interruptions of the photographic work necessitated by the alterations of the clock, by Mr. Rambaut's illness, which prevented his observing at night from April till August, and other causes, the number of plates exposed bears but a small proportion to what we hope to do in the future. On the whole there have been 55 plates taken, containing 136 exposures. Of these a considerable proportion are suitable for measurement. In particular, a photograph of the clusters in *Perseus*, taken on September 1 with two exposures of 10^m each, has occupied much time, both in measuring it and in investigating the methods and formulæ of reduction. We hope before long to be in a position to publish the results of the measures of this photograph, which are still in progress.

During the stoppage of the photographic work recourse was had to the working list of stars with large proper motion referred to in former reports. As in previous years, the meridian-circle and chronograph were used for this work.

In this connection there were 234 observations of R.A. and 186 of declination, 32 of collimation error, 8 of the errors of runs, 27 of level error, and 26 of the nadir point of the circle.

In addition there were 334 circle readings and 158 micrometer measures made with the meridian-circle, in connection with some experiments on the reflexion of light, which are not yet concluded.

Glasgow Observatory.

The operations at the Glasgow Observatory during the past year have consisted chiefly of meridional observations of telescopic stars, especially stars in Bessel's Zones, with the view of establishing the existence or non-existence of proper motion of sensible magnitude in cases wherein a comparison of star-places in the Glasgow Catalogue with previously observed places had left this question doubtful. It was intended to have the results published towards the close of last year, but circumstances have occurred which will cause a delay of a few months. It is to be hoped that the Scottish University Commissioners before concluding their labours will make some provision for promoting the efficiency both of the observatory and of the Professorship of Astronomy connected with it.

Due preparations were made for observing the total eclipse of the Moon of November 15, in accordance with the suggestions of M. Döllen, but the unfavourable state of the weather prevented their being carried into effect.

Liverpool Observatory, Bidston, Birkenhead.

The astronomical work has consisted chiefly in observations of stars with the transit instrument for the determination of clock errors. Preparations were made for observing the occultations of the stars in Dr. Döllen's list on the occasion of the lunar eclipse on November 15, but clouds obscured the Moon during the total phase.

Greenwich mean time has been communicated to the Port by the firing at 1 P.M. daily of the gun placed on the pier-head of the Morpeth Dock.

Two hundred and eighty-three marine chronometers have been tested at the observatory during the past year. We have no reason to suppose the thermal error, or correction due to change of temperature, remains constant for only a short period. In fact, our records prove that the reverse is the case.

The meteorological work has been continued as heretofore. No break has occurred in the records of the self-registering instruments.

Radcliffe Observatory, Oxford.

During the year 1891 considerable progress has been made in the preparation of a General Catalogue of Stars for zero points between 90° and 115° N.P.D.

A very approximate catalogue has been formed from the observations made during the years 1880–1890, both inclusive; and with these places the precessions and secular variations have been computed for the final catalogue for the whole of the stars, which number 5,363.

The North Polar Distances made in 1891 are completely reduced to mean place; the Right Ascensions will very shortly be ready for the formation of the Ledger and the Catalogue for the year.

The observations made in 1891 afford places for nearly a thousand additional stars; and the total number of stars included in the General Catalogue will be about 6,350. The whole of these stars have now been observed, with the exception of thirty, whose places will be secured in the earlier months of the present year.

The number of transits observed in 1891 has been 3,269, and the number of circle observations 2,780; but to secure these observations special watches have had to be arranged for during a part of the year.

The Sun and Moon have been observed with the transit circle at every opportunity.

With the Barclay equatoreal the last contact of the partial solar eclipse of June 6 was secured; forty observations of

fourteen double stars have been made; Encke's Comet was observed on August 12, September 10, September 30, October 4, and October 11; and Wolf's Comet was observed on four nights. The observation of the lunar eclipse of November 15 was prevented through cloud.

The meteorological observations have been continued as usual.

Oxford University Observatory.

During the past year the series of observations for the determination of the parallax of all stars of the second magnitude, conveniently situated for England, has been brought to a complete and, it is hoped, satisfactory conclusion. The results will be communicated to the Society at an early period.

All the plates necessary for the determination of the parallax of γ *Draconis* have been taken, and the measurements are completed. The observations extend throughout the year.

A long series of plates has also been completed for the parallax of the two very faint stars of comparison used in the determination of the parallax of α *Cephei*. The measuring of plates is commenced. The total number of photographs taken and measured for the purposes of the above computations much exceeds four thousand. The parallax of the second magnitude stars, referred to above, being completely finished, a group of stars bright and faint has been selected for the determination of their distances from the Sun, and it is not improbable that some interesting results may follow, owing to the fact of their being involved in nebulosity and having very nearly the same proper motions.

Very much time has been necessarily expended in the preparation of the new instruments to be used on the international chart of the heavens.

A considerable number of plates comprised in the zone assigned to Oxford have been completed.

The latter operations have been materially delayed by the necessity of examining the effects of wire-gauze screens in reducing the apparent brightness of stars by definite amounts, as proposed by a committee of the international chart. This method has not practically succeeded either at Greenwich, Paris, or Oxford. In consequence of this, a request was made to the Oxford Observatory to furnish charts and short catalogues of stars of the ninth and eleventh magnitudes, situated in convenient typical regions assigned by Professor Kapteyn. Six of these have already been circulated among the various observatories engaged in the work. These have required both time and attention to complete with available accuracy.

In the course of the observations made with the wire-gauze screens, several interesting and unexpected results have been

obtained. These have been communicated to the French Academy, and published by them in their *Comptes Rendus.*

Mr. Plummer was deputed to represent the University Observatory at the International Congress in Paris. By his long experience in stellar photography he was enabled to render valuable service.

Photographic plates have been taken, and photometric observations of the *Nova* in *Auriga* have been made whenever the state of the sky has permitted.

Temple Observatory, Rugby.

Mr. Highton has continued the measurement of position and distance of double stars with the 8½-inch refractor, and Mr. Seabroke has measured the velocity of motion of stars in the line of sight with the spectroscope on the 12-inch reflector.

A 15-inch silvered glass mirror, of 45 inches focus, has been mounted recently for the photographing of faint objects, and as soon as the weather permits operations will be commenced.

There has been a much larger attendance than usual of members of the School during the autumn months, so that our original work has been reduced in quantity.

Dr. Common's Observatory.

During the past year a new 5-foot mirror has been made for the telescope. This piece of glass has proved to be almost—if not quite—perfect, and the mirror is a most excellent one.

Some very fine photographs of nebulæ and the Moon have been taken, that will be laid before the Society.

A new grating spectroscope has been fitted to the 5-foot.

Work on plane mirrors has been carried on in the workshop.

Mr. E. Crossley's Observatory, Bermerside, Halifax.

As in past years, the work of this observatory has been chiefly the measurement of double stars, the observation of the phenomena of *Jupiter's* and *Saturn's* satellites, and occultations of stars by the Moon. Meteorological observations are taken daily at 9 A.M. and 3 P.M., and reports sent to the Registrar-General, Mr. Symons, and the local Sanitary Department. A number of double-star measures and the year's work on the satellites of *Jupiter*, &c., have been communicated to the Society. About one thousand measures of double stars were made in January, February, and March; these and all the measures made since 1881 will shortly be ready for publication.

The figuring of the 3-foot (B mirror) has been completed by Sir H. Grubb. It is a great improvement on the A mirror, with which Dr. Common took the photographs of the Moon, &c., in the possession of the Society. Many photographs of the Moon and other objects have been taken with the mirror, but, owing to the very bad observing weather throughout the autumn and early winter, no results of special interest have yet been obtained.

Wolsingham Observatory. (Rev. T. E. Espin's.)

The sweeps for stars of the third and fourth types have been continued as in previous years. The total number of new third-type stars detected is 120. Only one star of the fourth type has been found, this is—

D.M. + 31°·1388 R.A. $6^{h}\ 32^{m}\ 46^{s}\!\cdot\!7$ Decl. + 31° 35′·1 8·1 (1855)

The presentation of the charts of Argelander's Northern Heavens by Mr. T. W. Backhouse has given the opportunity of systematic zone work with the spectroscope, and during December seven hours of R.A. were examined at decl. +55°, and 31 third-type stars detected. In all five new variable stars were discovered during the year, they are—

			h	m	s		°	′			
(1)	...	R.A.	4	26	4	Decl.	+ 65	52·8	(1855)	discovered	Mar. 2
(2)	D.M. + 68°·398	„	5	25	22	„	+ 68	42·5	„	„	Feb. 16
(3)	...	„	5	32	42	„	+ 31	57·5	„	„	Jan. 31
(4)	D.M. + 36°·3852	„	19	59	6	„	+ 36	24·8	„	„	Sep. 10
(5)	...	„	20	11	54	„	+ 49	29·7	„	„	Sep. 10

Of these, Nos. 1, 3, 4 have a third-type spectrum; No. 2 is remarkable from the enormous size of the bands—unfortunately it was not observed at a maximum in 1891; No. 5 is probably type IV. Dr. Wolf's photographs of the *a Cygni* regions were compared together, and also with the charts of Argelander, and those stars marked which showed any large difference of magnitude on the photographs. Seven evenings in the autumn were devoted to the observation with the spectroscope of these objects, and 171 stars were thus examined. The variation of the star D.M. + 39°·4208 is confirmed by the photographs. Two nights were also devoted to a careful examination of the great *Perseus* cluster, with the object of definitely identifying the red stars therein. The meteorological instruments presented by Miss E. Brooke have been read daily. Alterations in the roof had to be made to fix the anemometer and sunshine recorder, and these were not finished till the middle of April. The instruments were then fixed with as little delay as possible. The observations of thunderstorms,

extending over a period of nearly twenty years, will shortly, it is hoped, be ready for the press; their publication has been delayed mainly for the purpose of completing some experimental work which opened up some unexpected results.

Rousdon Observatory. (Mr. C. E. Peek's.)

The establishment is maintained in efficient working order, and the observation of long-period variable stars is regularly carried on.

During 1891 observations were made on 167 nights, and 441 determinations of magnitudes were obtained, involving about 2,200 comparisons of the variables with stars of standard magnitude.

The working list was somewhat modified by the introduction of several circumpolar variables and the withdrawal of a few less favourably situated stars. The whole of the sixteen long-period circumpolar variables recommended by Professor Pickering as worthy of continued study are now regularly observed, the greater number having been under observation for the last six years.

In several cases a slight nebulosity has been suspected at minimum, and the attention of observers is requested to this point.

The usual observations for clock rating have been taken.

The equatoreal has a 6¼-inch O.G.

Mr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.

Photographic work has been steadily pursued at this observatory during the year ending December 31, 1891, and Crowborough Hill is found to be a more favourable locality than Maghull for this work.

The months of February, April, May, and September had the greatest number of clear nights. In the course of the year 196 photographs of stars, nebulæ, and clusters were obtained with exposures varying between 30 minutes and four hours respectively (besides many others with shorter exposures), enlargements of some of which, accompanied by explanatory notes, will in due course be submitted to the Society. Twenty-nine of the photographs were taken, with exposures of 90 minutes each, of that part of the sky indicated by Professor Forbes, in which he thought a planet might be found beyond the orbit of *Neptune*, but as there are yet to be taken two photographs to cover the whole of the region indicated, it is necessary to defer the report I shall have to make concerning Professor Forbes's hypothesis.

In the description given of this observatory in the *Monthly*

Notices (vol. li. p. 118) it is stated that the dome was constructed with two slits so as to permit both the reflector and the refractor being used simultaneously, but in practice it was found that the disadvantages of this plan outweighed the advantages, inasmuch as the division between the slits (two feet in width) being continuous over the vertical axis of the dome obscured part of the sky about the zenith during nearly two hours in Right Ascension. The dome has consequently been altered, and it has now one slit 4 feet 1 inch in width, extending from the horizontal continuously to 18 inches beyond the zenith.

Birr Castle Observatory. (The Earl of Rosse's.)

There is nothing special to report on the work of Birr Castle Observatory during the past year. Lord Rosse was absent, either abroad or in England, almost continuously for the first seven months, and the weather, which may have been about up to an average till his return, certainly changed for the worse afterwards. It was intended to obtain measurements of lunar heat during the eclipse of November 15, but only glimpses of the Moon through clouds and drift were obtained. The further prosecution of this work at every opportunity is kept in view.

Meteorological and other routine work has been carried on as usual.

Mr. W. E. Wilson's Observatory, Streete, Co. Westmeath.

During the past year the 2-foot reflector has been remounted by Sir H. Grubb. The old mounting was found to be too weak and unsteady for any photographic work, and it was therefore decided to have the instrument entirely remounted, and provided with driving clock and electrical control of the same type as the standard photographic telescopes. The instrument will be quite finished and ready for work early this year.

The photographic photometer described at the meeting of the Society on January 8 is still in Sir H. Grubb's hands, and as soon as it is received will be used in some work on star magnitudes.

The experiments on solar radiation, which have been in progress for some years, will be resumed with the aid of a large siderostat kindly lent by the Royal Society.

Adelaide Observatory.

During the past year the staff have been employed in re-observing the Weisse stars from the Equator to 15° south, including other stars not in the catalogue, down to the tenth magnitude.

This undertaking was commenced on April 27, Mr. Cooke, the first assistant, having special charge of it. Each star will be observed three times.

The following will show what has been done during 1891:—

No. of observations with Transit Circle in Right Ascension	...	3,204
" " " in Declination ...	...	2,342
No. of observations of Nadir	...	76
No. of determinations of Level error	...	91
" " Collimation	...	93

The reductions are well forward, and progress catalogues will be published from time to time. In addition to this, during the course of the year, careful determination has been made of the errors of division and flexure, besides special observations for colatitude.

It should be mentioned that a new transit clock by Frodsham has been added to the equipment; and the old clock has been converted into a mean-time clock, and is now being fitted to drop the time-ball at the semaphore, which has hitherto been dropped by hand contact. It is intended shortly to drop time-balls at Port Augusta and Port Pirio.

The mean-time clock will also transmit time signals to the different post and telegraph offices throughout the colony. The clocks at Parliament House are synchronised by means of hourly signals transmitted by the tower clock at the General Post Office, which is kept within a few seconds of mean time.

The equatoreal has been principally employed on *Jupiter*; occultations, eclipses, and transits of its satellites; and drawings, of which a very large and continuous series has been made by Mr. Sells.

In meteorology we have 350 stations, spread all over the colony, from Port Darwin, on the north coast, southwards, at which the rainfall is recorded. The returns are published monthly.

Weather reports are exchanged every morning with each of the neighbouring colonies, including Tasmania and New Zealand. These reports emanate from no less than 72 stations—viz. 13 in Queensland, 15 in New South Wales, 11 in Victoria, 17 in South Australia, 8 in West Australia, 5 in Tasmania, and 3 in New Zealand—and every telegraph office in the colony transmits a report, giving direction and force of wind, state of weather, and rainfall at 9^h A.M. From these are compiled a tabular statement and general report, an isobaric map, and a forecast is issued for the ensuing 24 or 48 hours, all of which are exhibited in the hall of the General Post Office and other places, as well as being published in the daily papers. The Goverment Astronomer is usually responsible for the forecasts.

In conjunction with Commander W. Usborne Moore, R.N.,

C.M.G., of H.M.S. *Penguin*, telegraphic determinations of the difference of longitude between the Adelaide Observatory and Roebuck Bay, Fremantle, and Port Darwin have been made.

The past year has been very dry—nearly the driest on record. The rainfall at Adelaide was 14·005 inches, or 6·563 inches below the average.

Hong Kong Observatory.

During the past year the time-ball was dropped as usual at 1 P.M., but there were many failures, and the signal was not so accurate as previously, owing to lack of skill on the part of the new assistants. A new standard clock has been received from Mr. James Brock, of 64 George Street, Portman Square, London. There is a very heavy pendulum swinging in an arc of over four degrees, which lessens the barometric co-efficients, but it is, as usual, over-compensated for temperature, the maker having left the zinc too long, so that it might be subsequently cut to the proper length. A mercurial compensation was ordered, and would have been preferred. As we have now two standard clocks, kept in rooms of different temperatures, it is to be hoped that great accuracy will be attained next year.

Observations of occultations of stars and phenomena presented by *Jupiter's* satellites were made with the Lee equatoreal, and shooting stars were also observed by the Director.

Absolute magnetic observations are now again made monthly.

Local meteorological observations and researches have been continued at the observatory and at the Peak. Reports were received from about forty stations in the Far East, and extracts have been made from log-books of vessels having encountered bad weather. These returns are at present being reduced for the construction of daily weather maps, by aid of which the typhoons of the past years will be investigated up to date. Daily weather reports and telegraphic storm-warnings were issued as usual.

The seventh annual volume was issued last spring, and the next volume is nearly ready for press. A third edition of the "Instructions for making Meteorological Observations in China" and "The Law of Storms in the Eastern Seas" have been issued. A considerable portion of the Director's time is taken up by furnishing information in response to inquiries about meteorological features, the deviation of the compass on board ship and similar matters. Instruments are also frequently sent to the observatory for verification, especially clinical and other thermometers.

Melbourne Observatory.

The work of the Melbourne Observatory for the year 1891 has varied little from that of former years. As usual the chief attention has been paid to the meridian work, which has been

considerably heavier since February last, owing to the Melbourne Observatory having undertaken to observe the guide stars for the photographic zones 10° to 14° south; these stars to the number of 922 have been observed in both co-ordinates at least three times; besides these a few stars have had their places determined for the survey department of New South Wales; a small number of stars compared with comets have also been observed. As regards the guide stars, in nearly all the instances stars of the required brightness have been found, and within the adopted limits from the centre of each plate. In a few cases, however, it was necessary to go outside the limits for a star of the required brightness, and in others the stars, although registered in Argelander's *Durchmusterung* as of the ninth magnitude, seem to be much fainter at the present time. Altogether this year 4,824 observations of Right Ascension and 3,193 of polar distance have been obtained with the new transit circle of eight inches aperture; in addition to which, owing to the abnormally cloudy weather in the spring season, about a hundred observations had to be taken with the old instrument of five inches aperture. It is intended to devote next year to the observation of the guide stars for the circumpolar photographic zones which have been assigned to this observatory.

Preparations and training for the Melbourne share of the photographic charting of the heavens have also added largely to the work. The photographic telescope arrived on 1890 December 27, and its erection was completed in January. The experimental work and training occupied the time of a part of the staff for many months, and now that work has actually been commenced it is found that during its progress the staff will be barely sufficient to cope with it, in addition to the increased meridian observing.

Unfortunately the astrographic work is now at a standstill for want of plates, the manufacturers in England having failed to keep up the supply. The early arrival of a consignment from M. Lumière of Lyons is now expected, which will enable the staff to resume without any serious loss of time.

The pressure on the staff has interfered with the extra meridian work, both with the great telescope and smaller instruments.

The routine meteorological and magnetic work was carried on continuously during the year, and photographs of the Sun were taken on every fine day with the photoheliograph.

As regards the preliminary work of the photographic charting, a great deal has been done in connection with determining the relations between photographic and photometric magnitudes with various makes of plates, varying exposures, and different kinds of fine nights. The results indicate numerous difficulties, and lead to a conclusion a little at variance with the later decisions of the Congress. It is found that, for the catalogue plates, to get safely measurable images of stars an exposure of 10^m is necessary; that a safely measurable image is never less than

3·75 mm. in diameter, and that to gain one magnitude (ratio 2·512) the time of exposure must be increased 3·16 times, or to gain two magnitudes it must be increased ten times. To account for these results being somewhat at variance with those adopted by the Congress, it may be suggested as being due to either different climatic conditions or some optical instrumental constant. The number of measures upon which the results depend is very considerable.

Natal Observatory.

The principal series of observations in progress at the observatory is the comparison of the declination deduced from observations made at the observatories in the northern and southern hemispheres, by a comparison, by Talcott's method, of the zenith distances of northern stars and southern circumpolars. During the year a number of additional observations have been obtained and reduced.

The work of observing equizenith distance stars, for determining the latitude of the observatory, has been brought to a conclusion. There have been obtained 1,022 observations of thirty-five pairs of stars. They have all been reduced and tabulated. Accurate places for all the stars used have been deduced from all the modern meridian observations that were available. The whole work is now completed and awaits publication.

At last there has been completed the work of comparing the entire mass of Greenwich meridian observations of the Moon, made during the years 1851–1888, with the theory forming the basis of Hansen's Lunar Tables. The results from these four thousand observations have been fully discussed, and the corrections deduced which are required by Hansen's Tabular Coefficients. Auxiliary tables are now being formed, founded on the corrections thus deduced, and the whole work is being prepared for publication as a memoir.

The final touches are also being put to the discussion of the observations of the position of the lunar crater Murchison A, made at the Arkley Observatory in the years 1879–1884, and at the Natal Observatory during the years 1883–1886.

Some, but not much, further progress has been made in preparing for publication two memoirs on the irregularities in the motion of the Moon, due to the perturbations of the planets, the first affording an investigation of the theory, and the second a numerical calculation of the value of some thirty-five terms. As the actual mathematical work in this complex investigation is completed, it is to be regretted that so much delay should ensue in the publication. Unfortunately the writing out of such work for the press cannot be done in little fragments in spare hours, and the heavy pressure of other duties has left no time for systematic work. The results are important, as they show that the method employed by Delaunay and his successors in their

determination of the values of coefficients of this kind is, as already stated, entirely incomplete, so that none of the values that have been made known are accurate.

Further progress has also been made in the reduction of the Durban Tidal Records.

A good deal of astronomical work has now accumulated at the observatory, and it is in contemplation to publish a volume of Observations and Results.

In July Mr. Grant resigned his position as Astronomical Assistant, and since then nearly the entire series of routine observation, calculation, and reduction have been made by the young ladies who have for some years so zealously aided in the work of the observatory.

Sydney Observatory.

At Sydney the year has been unusually cloudy and wet, and generally unfavourable for observations. The latter part of the year has been most unsuitable for photographic work, owing to the prevalence of thin cloud or haze.

A very fine micrometer for the pointer telescope has been made in the observatory, and a number of minor conveniences applied to the photographic telescope, including an improved box for charging the sensitive plates, which enables the operator to do the work better and more quickly.

It has been decided to publish a full description of the star camera, and the publication is now in a fair way of completion.

With the transit circle 1,330 transits in R.A. have been taken, comprising 714 stars observed in R.A. only, 616 stars in R.A. and N.P.D.; 165 of these belong to the photographic zone.

Azimuth has been determined 82 times, Collimation 280 times, Levels 365 times, Nadir 365 times.

The 1889 Catalogue has been completed; the 1890 Catalogue has been formed, and reduction to 1890 partly finished. The 1891 computations are complete, preparatory to formation of catalogue.

All unpublished R.A. and N.P.D. work has been examined to the end of 1890.

Four nights were devoted to determination of the longitude of Bourke Town, Gulf of Carpentaria, in conjunction with the trigonometrical survey staff of Queensland.

The Circle B was examined thoroughly at every degree.

The equatoreal work during the year includes measures of 93 double stars, made on 80 nights, comprising 590 measures of angle and 590 measures of distance.

Search was made for comet *Barnard* in May on two mornings without success, and for comet *Tempel-Swift* on two evenings with no result. Comet *Barnard* (Oct.) was observed on three evenings, and 62 comparisons made with 4 stars.

The transit of *Mercury* was observed on May 10.

The average definition during the year was very poor, fifty-six nights only being noted as fine; on fifteen of these, however, definition was so bad that nothing could be done.

The computations for the reduction of the double-star work are completed and ready for publication. The comet observations have been published.

Pending the final meeting of the Committee in Paris on 1891 March 31, to decide details of photographic work, the work in connection with the Milky Way has been extended, and the great rift across it in *Argo* photographed, with the result that the dark places do not appear on the photographs. The star camera has been used to investigate important regions, and the densest part of *Nubecula Major*, η *Argûs*, the Trifid Nebula, &c., with remarkably good results. In the neighbourhood of η *Argûs*, in parts specially examined by Sir John Herschel, the camera shows ten times as many stars, and entirely new features of nebula with $5\frac{3}{4}$ hours' exposure.

A part of the year has been devoted to a thorough re-examination of the focus, with the lens supported on three points, as by the maker, and supported all round. The images are slightly better with continuous support, but the 3-point support was adhered to, because other star cameras are so supported. The resulting focus gives good measurable images of stars $3''$ in diameter, some as low as $2''\cdot85$, probably smaller in clear, steady weather; but, as already stated, the weather during the focus experiments (*i.e.* October, November, and part of December) has been very bad.

Fifty catalogue plates have been taken, but some of these may have to be done again, owing to hazy weather.

Three *réseaux* have been obtained from M. Gautier, of Paris, beautifully made; but from some chemical change the silver is apt to develop troublesome *pin holes*, easily mistaken for stars.

The wire screen intended to facilitate the determination of 11 mag. stars was not received until October.

A volume, containing silver prints of the southern part of the Milky Way, has been published and distributed. Other papers in connection with star photographs have been published in the *Monthly Notices*, and *Proceedings of the Royal Society of New South Wales*.

Photographs were attempted whenever there was a break in the clouds; in all on 143 nights, but only fifty-two of these gave satisfactory results. October, November, and December were almost useless for the star camera, owing to thin haze—hot-weather haze. Exposures have been given on some of these nights up to thirty minutes, without getting a trace of 11 magnitude stars.

The weather-chart service has been maintained and improved; considerable improvement has also been introduced into the printing. The daily issue of two editions has been kept up for

public convenience, and the service is appreciated by the public. The maps are bound in monthly parts, and distributed to other observatories.

The general meteorological work has been kept up. The monthly reports up to the end of October have been printed and distributed. The rain report for 1890 has been seven months in the printer's hands. The volume of general meteorological results for 1889 has been printed, and is ready for distribution. All the reductions for 1890 are complete, and those for 1891 are in a forward state.

The total number of meteorological stations is now 1,238.

Mr. Tebbutt's Observatory, Windsor, New South Wales.

Notwithstanding that much cloudy weather prevailed during the early part of the year 1891, a considerable amount of work has been done. The transit instrument was employed on 175 nights, and 975 transits of stars, not exceeding 40 degrees of declination, were observed for local time only. Besides these observations many other meridian transits were observed for various purposes. The observations for instrumental errors have been 385 for level, 50 for collimation, and 186 for azimuth. No adjustment of the instrument was made during the year. At the beginning of the year the western pivot was 7″ too high, but it gradually fell till July, the coldest month, when the axis became level. The pivot then rose gradually, and recovered its former value at the close of the year. The collimation and azimuth errors have been as steady as in former years. The chronometer rate has been very satisfactory.

The following extra-meridian observations have been made with the 8-inch and 4½-inch equatoreals:—

Lunar occultations of stars, comprising forty-five disappearances, eleven reappearances, and one graze. The satisfactory result in this department is, in a great measure, due to the interest of Mr. R. T. A. Innes, of Sydney, who has kindly supplied the observatory with the prediction calculations of *Nautical Almanac* stars for the last eleven months of the year. Clouds, unfortunately, prevented the observation of the occultation of *Mercury* in daylight on December 3. Lunar occultations of stars are systematically observed here, in order specially to provide data for Professor Newcomb's investigation of the Moon's motions.

The observed phenomena of *Jupiter's* satellites are classified thus:—

Transit Ingress, I. 1, II. 2, III. 1. Transit Egress, I. 6, II. 3, III. 2. Occultation Disappearances, I. 4, II. 1, III. 1. Occultation Reappearance, IV. 1. Eclipse Disappearance, II. 1. Eclipse Reappearances, I. 3, II. 4, III. 1, IV. 1. Physical observations of some of the satellites were also made during their transits.

The transit of *Mercury* of May 9–10 was pretty well observed in both phases, particularly at egress.

Twelve excellent filar micrometer comparisons of *Venus* and *Jupiter* at their conjunction on April 7, and 107 similar comparisons of *Ceres* and neighbouring stars, between declinations $-26°$ and $-28°$, on August 15, 16, 17, 18, 19, 20, 30, 31, September 1, 2, 3.

Sixty-eight square bar micrometer comparisons of Comet I. 1891 (Barnard-Denning) on June 4, 11, 12, 13, 14, 29, July 2, 3, between declinations $-37°$ and $-47°$, and 105 of Wolf's periodical comet on October 9, 11, 30, 31, November 2, 3, 4, 7, December 17, 20, 21, 25, 26, between declinations $+10°$ and $-15°$.

Measures of the double stars *p Eridani*, *Lalande* 4219, *α Centauri*, 39 *Ophiuchi*, *κ Coronæ Australis*, *Brisbane* 6556, *h* 5075, and *γ Coronæ Australis*.

Determinations of the magnitudes of *η Argûs* and *R Carinæ*. No sensible change has taken place in the lustre of the former during the year, and a determination of the maximum (5·5 mag.) of the latter was obtained in March.

In addition to the work thus enumerated many observations have been made for determining constants in connection with the larger equatoreal. The 9^h A.M. meteorological observations have been carried on with great regularity, the past year being the twenty-ninth in this department of observation. The printed abstracts for 1886, 1887, 1888, 1889, and 1890 are now ready for distribution.

Finally, the instruments continue in good condition, and the library, which has now assumed fair proportions for a small establishment, continues to be enriched by many valuable presents from Colonial and foreign scientific institutions. This part of the report is very gratifying to the proprietor and encourages him to greater efforts in his labour of love.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets in 1891.

The past year has been the richest on record as regards the discovery of minor planets, no less than twenty-one having been added to the list, as compared with seventeen in 1875, twenty in 1879, fifteen in 1890.

The following is the list of discoveries:—

No.	Name of Planet.	Date of Discovery, 1891.	Discoverer.	Place of Discovery.
303	Josephina	Feb. 12	Millosevich	Rome
304	Olga	14	Palisa	Vienna
305		16	Charlois	Nice
306	Unitas	Mar. 1	Millosevich	Rome
307		5	Charlois	Nice
308		31	Borelly	Marseilles
309	Fraternitas	Apr. 6	Palisa	Vienna
310		May 16	Charlois	Nice
311		June 11	,,	,,
312		Aug. 28	,,	,,
313	Chaldaea	30	Palisa	Vienna
314		Sept. 1	Charlois	Nice
315	Constantia	4	Palisa	Vienna
316		8	Charlois	Nice
317		11	,,	,,
318		24	,,	,,
319		Oct. 8	,,	,,
320		12	Palisa	Vienna
321		15	,,	,,
322		Nov. 27	Borrelly	Marseilles
323		Dec. 22	Wolf	Heidelberg

It has been computed that 306 and 313 will each be at least 9·5 magnitude in favourable oppositions; 318 is interesting from

the almost exact commensurability of its period with that of *Jupiter*. From observations on September 24, October 9, October 21, Berberich deduces a period equal to *Jupiter's* ÷ 1·9987.

Palisa on August 14 discovered what was for a time supposed to be a new planet, but on examination it was found to be identical with (149) *Medusa*, discovered in 1875, but not observed since.

It is still uncertain whether the planet discovered by Borrelly on November 27 may not be identical with (156) *Xanthippe*, discovered by Palisa in 1875, but not observed since that year.

323 is interesting as being the first new asteroid discovered by photography; another asteroid registered itself on the same plate but was found to be identical with (275) *Sapientia*.

296 has been named *Phaëtusa*, 297 *Caecilia*, 298 *Baptistina*, 299 *Thora*, 300 *Geraldina*, 301 *Bavaria*, 302 *Clarissa*.

A. C. D. C.

The Comets of 1891.

Exclusive of the comets visible at the end of last year, the following comets have been under observation :—

(*a*) Discovered by Mr. Barnard at the Lick Observatory on March 29, and independently by Mr. Denning, of Bristol, on the following night. The comet was tolerably bright at the time of its discovery, having a tail 30′ long. It increased in brilliancy throughout the following months, but its rapid southerly motion soon prevented observation in the northern hemisphere. It was seen at the Cape in the middle of June, and at Cordoba in July, but appears to have been very faint and difficult to observe. The orbit, which is not definitely determined, is probably parabolic.

(*b*) A reappearance of Wolf's comet of 1884. First seen, but the observation not completely verified, by Dr. Spitaler, of Vienna, on May 1, and certainly seen by Mr. Barnard, with the 12-inch equatoreal of Lick, on May 3. The theoretical brilliancy of the comet at this date was slightly greater than at the time of the last observation in 1885, by Professor Young at Princetown. This interesting comet can make a very close approach to *Jupiter*, and in 1875 the perturbations by that planet were so great that an altogether new orbit resulted. During the last revolution, however, the perturbations have not been heavy, and the computations of Drs. Thraen and L. Struve gave a very close approximation to the actual place of the comet.

(*c*) A return of Encke's comet. Dr. Backlund, of Pulkowa, had prepared an approximate ephemeris to aid the discovery, but, not being able to take the full effect of per-

turbation into account, feared that the true path might differ some minutes from that predicted. When discovered by Mr. Barnard on August 1, however, the error of the ephemeris was only about 2′ in the arc of a great circle. The comet passed through its perihelion on October 18, and the apparent path of the comet is not favourable for post-perihelion observation.

(*d*) A return of the periodic comet known as Tempel$_2$–Swift, first seen in 1869, and again in 1880. The peculiarity of this comet is that the return to perihelion, with a period of five and a half years, is effected under conditions alternately favourable and unfavourable to observation. Consequently, in 1886 the comet was not seen, and the difficulties of prediction at this return were proportionately increased. M. Bossert prepared an ephemeris with very great care, bringing up the perturbations from 1880, and by this means Mr. Barnard was again successful in seeing the comet, though the perihelion passage, being about two and a half days in error, the observed place differed considerably from that predicted. Mr. Barnard saw the comet on September 27, and it was independently detected by Mr. Denning on September 30. At this time the theoretical brilliancy of the comet was nearly the same as that when the comet was last seen in 1869. This comet passed through its perihelion on November 17, and is still under observation.

(*e*) On October 3 Mr. Barnard discovered a telescopic comet in the constellation *Argo*, and moving to the south. The great southern declination, combined with its direction of motion, prevented observation in the northern hemisphere. The diminishing brilliancy, and the rather unfavourable position with regard to the Sun, are likely to prevent this comet being adequately observed, but the orbit, still imperfectly known, is probably parabolic.

It is impossible not to recognise the important service which Mr. Barnard has rendered to the section of cometary astronomy.

Among the more interesting contributions to cometary literature have been the discussion of the orbit of Comet, 1882, II. (the great September comet) by Dr. Kreutz, of Kiel, and an inquiry into the suggestion of cometary capture by planetary perturbation from M. Callandreau, of the Paris Observatory. In the former of these Dr. Kreutz returns to a subject which he had previously considered. After an elaborate investigation, in his first paper, of the form of the orbit, Dr. Kreutz had concluded that the centre of gravity of the comet coincided with one of the five nuclei, into which it will be remembered the head of the comet subdivided itself. The point selected by the

author was the nucleus (2), the point (1) being the condensation farthest from the tail. Further discussion, in his second paper, has now led Dr. Kreutz to the conclusion that it is impossible to localise with precision the centre of gravity of the comet, which he would now place between point (2) and point (4). The observations anterior to the separation of the general nucleus are equally well represented by an orbit based on the third as on the second point of condensation; and, from the character of these orbits, the author indicates that the division of the nucleus has been accompanied by a diminution of the semi axis-major, and that if, as is probable, the disintegration of the nucleus did not modify the position of the plane of the orbit, the comet entered into our system with a period of revolution between 770 and 1,000 years; but this uncertainty renders it impossible to trace the appearance of the comet in any historical records.

Dr. Kreutz also discusses the cause of the division of the nucleus, and rejects the hypothesis which would attribute it to the action of the solar atmosphere, suggested by the close approach this comet made to the Sun. A very small alteration in the velocity of the different parts of the cometary nucleus, roughly one-five-hundred-thousandth of the whole, would be sufficient to explain the rupture; and, considering the spectroscopic modifications which the nucleus exhibited at the time of the perihelion passage, it is not improbable that an adequate explanation may be found in the internal constitution of the comet itself. A force emanating from the centre of the nucleus, and extending itself regularly in all directions, would, if sufficiently great, produce an effect similar to that which has been observed.

In the other contribution mentioned above, M. Callandreau, following a line of investigation pursued by M. Tisserand, has examined the conditions which the action of planetary influence can have upon a comet moving in a parabolic orbit, and, in particular, how far the perturbations of *Jupiter* can explain the existence of a family of periodic comets of short period, possessing the characteristics with which we are familiar. He finds that the fact of direct motion, of the coincidence of the aphelia with the orbit of *Jupiter*, of the absence of hyperbolic motion, can all be explained by supposing the comet, originally approximately parabolic, to have encountered the sphere of *Jupiter's* activity at a particular angle with the planet's radius vector. On examining the orbits of all the known periodic comets M. Callandreau finds only one whose orbit apparently contradicts this theory of cometary capture. This comet is Encke's, and the anomaly is explained by supposing that its introduction into the solar system is due to the action of some planet inferior to *Jupiter*.

This subject has also received attention at the hands of Professor Newton, in the *American Journal of Science*, and if some

difficulties still remain unexplained, such as the large number of periodic comets—a number larger than the theory of chances suggests—much has been done to remove what was vague and unsatisfactory, and to bring the hypotheses within the range of extreme probability.

Total Solar Eclipses.

There have been no total solar eclipses of importance in the last two years, but several reports of the pair in 1889 have been published. Both the Washington University eclipse party and the Lick Observatory party have published their accounts of the eclipse of January 1, 1889, and the photographs have been beautifully reproduced by the Smithsonian Institution; and the Lick Observatory account of that of December 22, 1889, has also appeared. A comparison of the published photographs shows clearly the change of the corona between January and December as pointed out by Mr. Wesley (Observatory, No. 160), the longer rays of which are all definitely equatorial in January, but show a tendency to sweep round towards the pole in December; and this is precisely in accordance with the change to be expected during a return towards maximum Sun-spot activity.

The Washington report for January 1, 1889, contains reproductions of four negatives and of a drawing made from all the negatives; also of drawings by Professor Engler and of one by Señor Valle, who shut out the inner corona with a disc, and represents streamers of 7° or 8° in length. The enormous length of these streamers, as seen in favourable conditions, has now been confirmed at several eclipses, and it is to be hoped that the question of the possibility of photographing them may be soon answered more satisfactorily.

The report of the Lick party for January 1 contains only one small silver print of the corona with several diagrams drawn from the negatives, in some of which the actinic intensity is represented from measurements of the photographs; but the Smithsonian Institution have reproduced in all nine negatives on a uniform scale; so that there is no lack of material for discussion.

The Lick report for December 22, 1889, contains prints of three negatives.

No remarkably new conclusions are drawn by the observers. There are at present two rival American theories of coronal structure—one due to Professor F. H. Bigelow, and the other to Professor J. M. Schaeberle. In a paper printed by the Smithsonian Institution the former contends that the streamers follow the lines of force of a certain distribution of electric potential; in the Lick Observatory report for December 1889 Professor Schaeberle compares the photographs of coronas with those of a

model globe with straight spines, arranged in a certain way, and finds a satisfactory resemblance. But it is necessary in the latter case to establish an annual variation of the corona, for which the evidence seems incomplete.

Professor Harkness's work on the Co-ordination of Astronomical Constants.

"It has been customary to endeavour to determine the solar parallax as if it were an independent constant, and the result is a mass of discordant values, all of which are more or less affected by constant errors, and none of which command anything like universal assent. But, in truth, the solar parallax is not an independent constant." It is entangled with the lunar parallax (P), the constant of luni-solar precession ($\mathfrak{P}$), the constant of nutation ($\mathfrak{N}$), the parallactic inequality of the Moon (Q), the constant of the Earth's lunar inequality (L), the constant of aberration (d), the light-equation (θ), the velocity of light (V), the mass of the Earth (E − M), the mass of the Moon (M), and the compression of the Earth (ϵ); and "it should be determined simultaneously with all these quantities by means of a least-square adjustment."

Professor W. Harkness, therefore, determined to undertake this very heavy piece of work, and the results appear in an appendix to the *Washington Observations* for 1885, under the title, "The Solar Parallax and its related Constants, including the Figure and Density of the Earth." His first care is to collect all the observed values of the quantities to be dealt with, and this compendium alone would render the work valuable. He adopts a single mean value in each particular case by a rather rough-and-ready process, which is possibly as good as any more elaborate method of weighting, but which is certainly open to criticism. These selected means are his raw material, and are to be submitted to the beautiful machine known by the name of least squares. The machinery works smoothly and satisfactorily in the skilful hands of Professor Harkness, and his definitive results are perhaps the best that can be obtained from his interpretation of the observations. The general result is that of the twelve independent variables selected above, the mass of the Moon was most in error, the probable error of the new determination being reduced to one-tenth of its previous value by the least-square solution. Important alterations are also made in Q, θ, and E; and next in order come the solar parallax and the nutation. The other constants are not seriously affected. The final table of definitive results for the epoch 1850·0 is as follows:—

Quantities.	Observed values.	Corrections by adjustment.	Adjusted values.
p	8″.834 ± 0″.012	−0″.0249	8″.8091 ± 0″.0057
P	3422.69 ± 0.17	−0.15	3422.54 ± 0.13
$\mathfrak{P}$	50.3570 ± 0.0035	+0.0001	50.3571 ± 0.0035
$\mathfrak{N}$	9.233 ± 0.016	−0.0126	9.2204 ± 0.0086
Q	125.46 ± 0.49	−0.509	124.951 ± 0.082
L	6.514 ± 0.023	+0.009	6.523 ± 0.019
α	20.466 ± 0.016	−0.011	20.455 ± 0.013
θ	497ˢ.0 ± 1ˢ.4	+ 1ˢ.01	498ˢ.01 ± 0ˢ.31
V	186347 ± 51 (miles per sec.)	−10 (miles per sec.)	186337 ± 50 (miles per sec.)
E	0.000003005 ± 0.000000023	+0.0000000051	0.0000030561 ± 0.0000000058
M	0.01271 ± 0.00031	−0.000375	0.012335 ± 0.000036
ϵ	0.003375 ± 0.000046	−0.000044	0.003331 ± 0.000032

Not the least important part of the memoir is a series of remarks on the direction which future investigations should take to improve the system of constants as rapidly as possible. A study of the factors for the probable errors in the course of the work shows clearly that the following pieces of work are eminently desirable:—

"1. The parallax of the Moon should be determined by the diurnal method, at one or more stations as near as possible to the Equator.

"2. The observatories in the northern and southern hemispheres should co-operate with each other for two or three years in systematically making meridian observations of the Moon to improve our knowledge of its parallax.

"3. Pendulum experiments should be made at a large number of stations, located partly in the neighbourhood of the Equator, and partly as near as possible to the Poles. Experiments in middle latitudes are also desirable but somewhat less necessary.

"4. New determinations of the constants of aberration and nutation should be made by as many different methods as possible.

"5. The meridian observations of the Sun, accumulated at the Greenwich and Washington Observatories during the last fifty years, should be discussed in such a way as to deduce from them the most probable coefficient of the lunar inequality of the Earth's motion.

"6. New determinations of the solar parallax should be made by observing *Mars* during its opposition in 1892, and also

by observing such asteroids as may come into favourable positions for that purpose.

"7. The measurement of some of the great arcs included in the scheme of the U.S. Coast and Geodetic Survey should be completed as soon as possible."

The Solar Parallax.

Since the last Report our Associate Prof. Auwers has published in the *Astronomische Nachrichten*, No. 3,066, the value of this constant from the heliometric observations made by the German expeditions in 1874 and 1882. Taken, as these were, on a uniform system by trained observers, and with instruments as nearly identical as possible, there can be no doubt that they deserve great weight.

Each single measure of the distance or reading between two limbs admits of the deduction of an equation of condition of the form—

$$n + \frac{s}{1000} \mathrm{N} = a \cos d\alpha + b d\delta + c d\pi \pm c'' \pm d\mathrm{R} \pm d\nu \pm \gamma,$$

where s denotes a correction to the scale value for 1000″, which is personal to each observer; and the last four unknown quantities are constants (c'' for the station and the other three for the observer), which admit of elimination by suitable combinations of the observations. Every *complete determination*, consisting of sixteen readings by the same observer, allows these four constants to be determined or eliminated from the mean equation; four readings, suitably varied, constitute a quarter determination, and eight a half determination. It would, therefore, be possible to form equations containing only s and the three corrections to the right ascension, declination and parallax, by using the observations in groups of sixteen, while s is independently determined for each observer, save in the case of Löw at the Mauritius in 1874. On this account the group of sixteen observations made by Löw is eventually omitted from consideration.

Instead, however, of taking these groups, and by meaning their equations of condition eliminating the four constant errors, Prof. Auwers has preferred to determine the most probable value of these errors for each observer or station, and to substitute them in the individual equations, in order that these may be reduced to means for groups by the use of the weights. Seventy-six quarter determinations were thus made for the transit of 1874 and 108 for that of 1882, and these are obtained as equations, each of the value of one, from complete determination. For the transit of 1874:—

6 at Tschifu.	6 at Auckland.
4 at Kerguelen I.	3 (including Löw's) at Mauritius.

Also for 1882—

6 at Hartford.	7 at Bahia Blanca.
3 at Aiken.	9 at Punta Arenas.

In each of these equations is now included a term for the effect of a small residual correction due to the observer, and in those for 1874 one depending on a residual error of longitude.

These equations of condition are then treated as of equal weight, and there result the following corrections, in which the effects of the longitude corrections in 1874 are shown to be insensible, and those of the observers' scales assumed to be so. $\Delta\alpha$ and $\Delta\delta$ refer to Leverrier's tables:—

	1874 Dec. 8.	m. e.	1882 Dec. 6.	
$\Delta\alpha =$	$+4''.65$	$\pm 0''.284$	$+9''.11$	$\pm 0''.124$
$\Delta\delta =$	$+2.31$	± 0.097	$+1.99$	± 0.064
$\pi =$	8.877	± 0.043	8.879	$\pm 0.037.$

The mean errors above depend on a determination of the mean error of a single measure derived from observations of the Sun's diameter at 45° ZD, on the hypothesis that closing and opening measures are liable to equal errors. A discussion, however, shows, as certainly as unexpectedly, that fifteen out of the seventeen observers make the last observations more certainly, and in the two outstanding cases the determination of the mean error is unsatisfactory. Then, though the assumed mean errors in the two series are nearly the same, a close examination of the residuals shows that they are not similar. This shows that there must have been departures in the same direction from the normal state, which lasted some time, and which, it is considered, can only be ascribed to a real deflection of the rays which reach the eye; such deflections would only occur when the zenith distance is great, and it is just in such cases, or when the observations are taken through breaks in the clouds, that these peculiarities occur. They do not affect the observations for 1882, but those of 1874 require an increase of probable error on these accounts. Moreover, though the scale values in 1882 are satisfactorily determined, so that their probable error cannot affect the parallax in the third decimal place, it is otherwise in 1874, where an increase is wanted; the probable error of π, corrected for all these causes, is $\pm 0''.062$ for 1874.

The high value of the parallax determined from these observations has led to a re-examination. There is a doubt which of two chronometers was used at the Mauritius (which was the station where one of the three full determinations had been rejected for doubts about the scale); the remaining two were by the same observer, and one seemed to have considerable error which can be explained either by the low altitude or a

wrong assumption as to the chronometer used. The last explanation would lead to an increase of the parallax by 0″·007.

Prof. Auwers then shows that the rejection entirely of the Mauritius observations, and also of those in China by one of the observers, would only decrease the parallax by 0″·002.

Finally the deduced corrections for $d\,\alpha$, $d\,\delta$, $d\,\pi$ were substituted in the equations for each single reading, a process which led to the rejection of two observations whose discordance had escaped notice, and to the confirmation of a suspected error of the time in another, which was now corrected, and the corrections to the assumed data having now been determined, they appear—

	1874 Dec. 8.	1882 Dec. 6.
$\Delta\alpha =$	$+4''\!\cdot\!69$	$+9''\!\cdot\!13$
$\Delta\delta =$	$+2\cdot30$	$+1\cdot99$
	m. e.	m. e.
$\pi =$	$8''\!\cdot\!873 \pm 0''\!\cdot\!062$	$8\cdot883 \pm 0\cdot037$

and the mean value—

$$\pi = 8^{s}\!\cdot\!880 \text{ with a mean error } \pm 0''\!\cdot\!032 \text{ or probable error } \pm 0''\!\cdot\!022.$$

The Diameter of the Sun.

The heliometers used by the German expeditions for determining the Solar Parallax were employed before despatch and after their return home, as well as at the selected stations, for measuring diameters of the Sun. The result is about 2,809 diameters, measured in various proportions with five instruments, each being the result of four readings of the scale.

These measures (*Ast. Nach.*, No. 3,068) have been arranged in groups, the observations for each heliometer subdivided for each observer and place (which is of course synonymous with time) of observation. The groups are separately weighted; first provisionally, when thirty measures on ten separate days are considered to be so independent of all but constant errors that they may have a maximum weight 10, subject to a reduction on account of uncertainty of scale determination; and then a second set of weights is given, which serve to combine the observations of one observer only.

Of the earlier observations some were made without the screens over the object-glasses, and this circumstance, as well as the fact that the screens in the last series were denser than those in the first, gives some idea as to the residual effects of refraction. The first mean results are—

1st series	Without screen	$1919''\!\cdot\!30$ at mean distance.
	With "	$1919\cdot32$
2nd series	" "	$1919\cdot32$.

Nevertheless, Prof. Auwers considers that heliometer D seems to give a smaller image than A, B, and C, which agree ; and, moreover, that the screening of the object-glass in this instrument reduces the image. He therefore proceeds to find instrumental errors for the five instruments, though it is confessedly not easy to do this very satisfactorily. Those found vary from $-0''\cdot20$ for heliometer B to $+0''\cdot18$ for heliometer D.

Having now applied these, he proceeds to collect the results for each observer and take the means, using the appropriate weights, and to arrange them in order of magnitude. The results of the twenty-nine observers now clearly show a personality in observing, the greatest value being nearly $2''\cdot0$ above the least. Weights are roughly assigned, and the resulting mean diameter of the Sun is $1919''\cdot26$.

Setting aside now provisionally those values which differ by more than half a second from the mean, there remain twenty whose mean is $1919''\cdot32$, and this value makes the greatest departures either way nearly equal. Of the nine reserved results three are very weak, and the remaining six are by observers who have shown a change of habit—suddenly in the case of three, and gradually in the others. It would, perhaps, be best to take the mean of the twenty good observers as $1919''\cdot32 \pm 0''\cdot07$; but, in order to get rid as far as may be of personality, it is preferred to take the greatest possible number of observers, and the final result offered is $1919''\cdot26 \pm 0''\cdot10$.

Some of these observations were made in the direction of the solar axis and equator, others in position-angles, 0°, 30°, 45°, 60°, and at right angles to these, and, being made at varying times of the year, they are practically more or less over the whole circumference. From the nineteen sets made in the equator and plane perpendicular to it is deduced an excess of the polar axis of $0''\cdot026$. Again, from the twenty-seven other sets is deduced an excess of $0''\cdot053$, giving a general mean of $0''\cdot032$. To this Prof. Auwers assigns a mean error of $\pm 0''\cdot023$, which, of course, shows that the observations do not suffice to determine any difference.

Prof. Auwers remarks that if this value of the polar diameter be in error it must be too large; still more, then, must those used in the ephemerides be so, and he suggests that his value should be used as more accurate. There is probably no determination of this Constant in existence which depends on so many observations by various observers with five different, though similar, instruments.

The Diameter of Venus.

During the transits of *Venus* in 1874 and 1882 the opportunity was taken to make measures of *Venus* on the Sun with the heliometer. Seventeen complete determinations were obtained in varying position-angles, but Prof. Auwers (*Ast. Nach.*, No. 3,068)

considers that these show no evidence of a departure from circular form, while his observations at Luxor in 1875 prove that there is none. These observations, then, give eleven determinations by different observers, to which may be added a twelfth at Luxor.

An examination shows that the personality of observation is very similar to that in the case of the Sun. Applying, then, the personal and instrumental errors deduced from the far more numerous solar observations, and excluding the determinations of three observers, which are considered anomalous, the value from the remaining nine is 63″·544, at a distance whose log is 9·422261.

Every four measures of the distance between the limbs of the Sun and *Venus* admit of a value of the diameter of *Venus* being deduced from them. This has been done, and the resulting value from seventeen observers is 63″·75 for the same distance; but it is considered that this is affected by a residual error similar to personality, and should not be mixed with the definite result before given.

The diameter at distance 1 is deduced as 16″·80. The difference between this and the value obtained off the Sun by three observers at Punta Arenas is ascribed to the effect of the atmosphere of *Venus*, and the final value of the diameter of the body of *Venus* at distance 1 is 16″·80, or 16″·87, if Auwers' observations of 1875 have applied to them a correction which he experimentally determined.

The Rotation of Venus.

In the Report of the Council for February 1891 an account was given of the interesting and important researches of Schiaparelli on the rotation of the planet *Venus*. He arrived at the conclusion that the rotation was very slow, and that the period was probably the same as that of her revolution round the Sun. The diurnal changes noticed by previous observers, which led to the adoption of 23^h to 24^h for the period of rotation, must be regarded as due to the circumstances of observation, and not to a real change in aspect of the planet. M. Niesten, of the Brussels Observatory, has since challenged these assertions and insisted on the reality of the diurnal changes, which he had ample opportunity of watching while constructing, in conjunction with M. Stuyvaert, a remarkably fine series of drawings of *Venus* in the years 1877–1890. The drawings themselves, taken alone, would appear to allow of either a rapid or a slow rotation. Even the point raised by M. Terby, to whom the memoir was referred for criticism, and whose somewhat hostile criticism is printed at length with M. Niesten's memoir, is not very conclusive. M. Terby points out that two drawings of the planet on July 14, 1881, by M. Niesten, and on September 11, 1884, by

M. Stuyvaert, are almost identical; but that the short rotation period of De Vico would require the phases to differ on these occasions by 180°, while Schiaparelli's period would make them the same. It must be remarked, however, that a great number of rotations would have meanwhile elapsed on De Vico's hypothesis; and, if this wonderful pair of drawings be accepted as giving correction to the period, this correction would amount to little more than a minute of time; though it might still not be possible to reconcile the intermediate drawings. But M. Niesten insists on the short rotation period of 23^h chiefly because he and M. Stuyvaert believe they have seen rapid displacements, relatively to the terminator, of both bright and dark spots. And it is probably to the reality of such apparent motions as these that the attention of the best observers must be directed in the future, with a view to settling this most important question.

Dr. L. Struve's Determination of the Moon's Semi-diameter from Occultations observed during the Total Lunar Eclipse of October 4, 1884.

In response to Dr. Döllen's appeal for co-operation among astronomers in observing occultations during the total eclipse of October 4, 1884, observations were received at Dorpat of 239 immersions and 175 emersions of fifty-six stars at forty-two places. At the eclipse of January 28, 1888, with better weather conditions, the number was more than doubled, but, as the exact places of the stars there observed are not yet determined, Dr. Struve confines his attention to the results of 1884, with which he hopes shortly to combine those for 1888.

For a first approximation Dr. Struve assumes k (the ratio of the Moon's radius to the Earth's equatorial radius) 0·2725, and for the Moon's mean parallax $57' 2''\cdot 27$. The geocentric places of the Moon are taken from the American Ephemeris, and therefore include Newcomb's corrections to Hansen's tables. Having first rejected all doubtful observations, he obtains 349 equations of the type

$$\Delta r + b\Delta\alpha + c\Delta\delta + d\Delta\pi = n;$$

where Δr, $\Delta\alpha$, $\Delta\delta$, and $\Delta\pi$ represent respectively corrections to the assumed radius, geocentric R.A., declination and parallax of the Moon. From these he seeks to determine the values of the unknowns by the method of least squares. Upon considering the weights he finds that they vary between narrow limits, and as in any case these limits must rest upon assumptions, he has decided to give all the equations equal weight. Thus he derives four normal equations. The correction to the assumed parallax obtained by direct solution from these is affected with

such a large probable error that Dr. Struve gives his final results in terms of $\Delta\pi$, pending the determination of π from the reduction of the 1888 eclipse observations. These results are—

$$\Delta r = +0''.334 - 0''.281\ \Delta\pi \pm 0''.073$$
$$\Delta\alpha = -0.005 - 0.143\ \Delta\pi \pm 0.107$$
$$\Delta\delta = -0.204 + 0.711\ \Delta\pi \pm 0.119$$

and from the above value of Δr

$$\Delta k = +0.000098 - 0.000082\ \Delta\pi \pm 0.000021\ ;$$

whence

$$r = 15'\ 32''.85 - 0''.281\ \Delta\pi \pm 0''.07$$
$$k = 0.272598 - 0.000082\ \Delta\pi \pm 0.000021\ ;$$

which must be regarded as very close approximations.

For the P.E. of a single observation he obtains the unexpectedly large value $\pm 1''.34$.

As regards observations at individual stations, the discordances show traces of systematic deviation in three instances only.

Finally, upon searching for indications of ellipticity, Dr. Struve finds that there is no systematic deviation of the form of the disc from a circle, a result fully in accordance with heliometer measures. A. E.

Herr Hartmann's Determination of the Increase of the Earth's Shadow during Lunar Eclipses.

Dr. Hartmann has investigated the amount by which the Earth's atmosphere increases the diameter of the section of the shadow during a lunar eclipse, and published his results in a paper with the title 'Die Vergrösserung des Erdschattens bei Mondfinsternissen' (*Abhandlungen der math. phys. Classe der K. Sächsischen Ges. d. Wissenschaften*, vol. xvii., Leipzig, 1891). Since the time of Tobias Mayer this increase has, in computations for some of the astronomical ephemerides, been assumed $= \frac{1}{60}$, although nothing is known as to the manner in which this quantity was determined. Several attempts have been made to find a correct value of the co-efficient, but hitherto only the observed duration of the eclipse of each lunar spot has been made use of, so that a great number of observations of only immersion or emersion had to be discarded. Dr. Hartmann has preferred to deduce from every single observation of the contact of the shadow with well-defined lunar formations the corresponding increase of the diameter of the shadow. In order to be sure that the unavoidable uncertainty

of the results of the observations is not increased by the use of approximate formulæ, the author of the memoir before us first discusses the formulæ required for the investigation, and applies them to the reduction of all the observations of lunar eclipses since 1800, those anterior to this date being too uncertain owing to instrumental deficiencies. As the personal bias of the observer must introduce a considerable uncertainty in the observation of the indistinct limit of the shadow, only such eclipses were used which had been observed independently by several observers. There were thirty eclipses of this class, of which two, however, were excluded after the completion of the investigation, as the materials were insufficient. Many erroneous identifications of lunar formations were detected and rectified. The places of the Sun and Moon were directly computed for each eclipse from Leverrier's and Hansen's Tables respectively for two epochs, which for total eclipses were taken about the mean of the observed times of immersions and of emersions respectively, as the data given in the ephemerides—viz. the places for the time of opposition with the hourly variation of both co-ordinates, were insufficient. The result of a most thorough discussion of 2,920 observations is, that the increase of the semi-diameter of the shadow at mean lunar parallax is $= 48''\cdot 62$. Throughout the investigation it was found that the immersions gave greater values for the increase than the emersions, as if the observers were inclined to anticipate the moment of contact with the shadow, while the shadow seems to decrease in size towards the middle of the eclipse and to increase after it. These and other phenomena, among which may also be mentioned the rule that total eclipses give a smaller value of the increase than partial ones, must be left for examination by the aid of photography. The final result of $48''\cdot 62$ (to which corresponds a coefficient of increase $= \frac{1}{50\cdot 79}$), can, however, in any case hardly be changed more than $2''$ or $3''$ by the use of new observations (though experienced observers may be able to see about $3''$ further into the shadow), and it seems, therefore, desirable that the use of Tobias Mayer's value of $\frac{1}{60}$ should be abandoned for that of $\frac{1}{50}$.

J. L. E. D.

Lunar Radiant Heat.

The fourth volume (series 2) of the *Scientific Transactions of the Royal Dublin Society* contains a memoir on the measures of the Moon's radiant heat as made by Dr. Boeddicker at Birr Castle Observatory during the total eclipse of January 28, 1888, with an introduction by the Earl of Rosse. In this introduction Lord Rosse gives a brief outline of his earlier experiments in the measurement of lunar radiant heat,

touching on the great difficulties which encompassed the work, and referring to the chief inferences to be drawn from his results—viz., that the Moon's heat contains a much larger proportion of rays of low refrangibility than the Sun's, and that the maximum of heat radiated from the Moon falls, if anything, before rather than after the time of full. This last result suggested the advisability of trying whether during a total lunar eclipse the minimum of heat would fall before or after mid-totality. Attempts were accordingly made during the eclipses of 1872 and 1884, and on the latter occasion Dr. Boeddicker's observations appeared to show that the minimum of heat fell later than the minimum of light, and that whilst the diminution of heat proceeded faster than the diminution of light, its recovery was much slower. The eclipse of January 28, 1888, proved much more favourable than the previous eclipses had been, the sky being quite clear, and Dr. Boeddicker was able to obtain a very satisfactory series of observations, which are given in detail in the present memoir, together with the deduced theoretical curves for both this eclipse and that of 1884. The results obtained in 1884 were fully confirmed, the radiation falling considerably before the commencement of the eclipse, and "not returning to its standard value until 1 hour 40 minutes after the last contact with the penumbra." Dr. Boeddicker considers it established, after making every reasonable allowance for the uncertainty and difficulty of the research, that the decrease of heat had begun quite three minutes before the first contact with the penumbra, a conclusion which would imply that the Earth possessed an atmosphere capable of exercising a distinct heat-absorption at a height of 190 miles.

The Distribution of the Moon's Heat.

A memoir, bearing a very interesting relation to that of Dr. Boeddicker's, has been published by the Utrecht Society of Arts and Sciences, it being the essay which obtained the prize offered by that body for the determination of the heat given by the Moon in its different phases. One of the principal subjects pointed out by Dr. Boeddicker as requiring systematic observation was that of the varying radiation of different parts of the lunar surface, and this is one of the chief points to which Mr. Frank W. Very, the author of the memoir in question, has given attention.

Mr. Very's observations were made with a Langley's bolometer, together with a sensitive galvanometer. An image of the Moon about 1·2 inch in diameter was thrown upon a white card, upon which the details of the surface could be readily distinguished by means of a concave silver-on-glass reflector. A circular hole in this card, of an area a little more

than $\frac{1}{80}$ of the apparent disc, allowed the sensitive surface of the bolometer to be exposed. The method of observation consisted of a reading from the Moon taken between two readings from a blackened copper screen, containing water at a known temperature, which could be readily interposed in the path of the light at the observer's will. Comparisons were also made on every evening between the radiation from the screen and from the sky.

Bad and indifferent observations were rejected, and those only of the eight most favourable nights were retained, the dates ranging from January 12 to April 15, 1889. The results are presented in a series of charts, and in tables which exhibit the general effect at a glance.

Briefly, these results may be summarised as follows:—The maximum for light is much more pronounced than that for heat, so that the visible rays form a much larger proportion of the total radiation at the full than at the partial phase. Next, the heat areas are eccentric, having their greatest extension towards the west; the diminution of the heat in the third quarter of the lunation is slower than its increase in the second. And, lastly, there is a fair agreement between Mr. Very's results and those of Lord Rosse, although so differently obtained. Thus the result Dr. Copeland obtained in 1870, that the greatest heat was attained before the full, is confirmed by the present series of observations.

Mr. Very's researches open up a new field, as previous investigations have dealt with the radiation of the Moon as a whole, whereas his method deals with that from numerous small portions of its disc under various conditions of phase, thus affording much additional information of a kind entirely new.

The Motion of Hyperion.

The attempts to get forward in solving the very interesting problem offered by the motion of *Hyperion* have been much hampered by the uncertainty and insufficiency of the data upon which they have to be founded. The deduction of these data from the observations cannot be properly effected without some approximate knowledge of the more telling inequalities of the motion, and, though the general form of these inequalities has been known since 1884, the question of their values in the real orbit has yet to be answered. It is therefore satisfactory to learn from a paper of Dr. Hermann Struve, published in No. 3,060 of the *Astronomische Nachrichten*, that a preliminary discussion of some of the observations of *Hyperion*, which he has been enabled to make during the last five apparitions of *Saturn*, 1887–91, has allowed him to deduce approximately the coefficient and period of the chief inequality or libration of the mean longi-

tude, and thus to account for a great portion of the apparent irregularities of the mean motion which the observations have shown. It is sufficient to know that the amplitude of the deduced libration is 9°, and the period 641 days, in order to understand that it must be duly allowed for in the deductions of osculating elements of the orbit, though the observations may not extend over more than a short period. The step forward thus gained will facilitate further steps, and though progress in the solution of the problem may be slow, there is good hope that it will be steady. A. M.

The Star Catalogue of the Paris Observatory.

The second instalment of this great work has recently been published—*i.e.*, that portion of it which contains the places of stars from 6^h to 12^h of R.A. The first portion of the Catalogue appeared in 1887, and the part now published is strictly a continuation of it. The Paris Catalogue is in reality three catalogues—viz., the observations made from 1837–53, and reduced to 1845·0; those made from 1854–67, and reduced to 1860·0; and those made from 1868–81, and reduced to 1875·0. The stars are arranged in order of their R.A. at the Epoch 1875·0. The programme which was carried out for so many years at Paris included the re-observation of as many of Lalande's stars as possible. The present volume extends to No. 14,783 of the Catalogue, corresponding to No. 22,725 of Lalande's Catalogue (Baily's). The Catalogue has been prepared for publication by M. Gaillot, with the assistance of M. Bossert. The latter has also prepared a very valuable Memoir on the proper motions of the stars whose places are given in the Catalogue, deduced from a comparison of the Paris places with any others that may be available. Every effort appears to have been made for the detection and correction of errors in the work, and the Catalogue when completed will doubtless be one of the most valuable publications of its kind.

Second Munich Catalogue of 13,200 *Stars for the Epoch* 1880·0.

This is a catalogue of faint stars (7–10 mag.) observed with the meridian circle of the Munich Observatory during the years 1884–88. The stars observed are chiefly those for which there was but a single observation in the Catalogue deduced from Lamont's zones mentioned in last year's Report, or the positions of which were for one reason or another doubtful. So that the present Catalogue is to a certain extent supplementary to the First Munich Catalogue, but contains the places of a large

number of stars deduced from recent observations, which will be useful to working astronomers in a variety of ways. The positions depend on Auwers' Fundamental Catalogue, the apparent places of the standard stars having been taken from the ephemeris published in the *Berliner Jahrbuch* for the different years. The stars whose places are given in the Catalogue are situated within about 25° of the Equator both north and south. The probable error of an observation is found to be $\pm 0^s{\cdot}081$ for a transit observed over four threads and for a mean declination of 10°, and $\pm 0''{\cdot}85$ for a declination when the circle is read by two microscopes.

Professor Seeliger, the Director of the Munich Observatory, under whose direction this Catalogue was reduced and prepared for publication by Dr. Bauschinger, is doing good work at the observatory, both in the series of observations which are being carried out there and also in the prompt publication of the results, so as to render them available to astronomers generally.

Pulkowa Catalogue of 5,634 *Stars for the Epoch* 1875·0.

This Catalogue is deduced from observations made with the Pulkowa meridian-circle during the years 1874–80. The places of the stars have been reduced and the Catalogue prepared for publication by Herr Romberg.

The stars whose positions are given in the Catalogue are of various classes—many double stars from the lists of W. and O. Struve, stars with large proper motions, stars used for longitude and latitude determinations, stars used for comparison with nebulæ, &c. The total number of observations exceeds 32,000. The positions of the fundamental stars are included in the Catalogue, and a comparison of their places with the positions of the adopted standard Catalogue is given for the determination of systematic error. The Zero-point for the declinations was originally determined from observations of the collimators, but from 1878 onwards the adopted positions of the fundamental stars were used for this purpose.

The probable error of an observation is found to be—

For a fundamental star	$\epsilon_\alpha \cos\delta =$	$\pm 0^s{\cdot}036$,	$\epsilon_\delta =$	$\pm 0''{\cdot}34$;
„ an ordinary star	„	$\pm 0{\cdot}038$,	„	$\pm 0{\cdot}34$;
„ a star of mag. 7–10	„	$\pm 0{\cdot}051$,	„	$\pm 0{\cdot}40$.

A comparison of the star places of this Catalogue is given with (amongst others) the Greenwich Ten-year Catalogue for 1880. In the mean the difference of R.A. at the Equator $= +0^s{\cdot}024$ (Pulkowa—Greenwich); there is a very close agreement in declination between the two Catalogues; that in R.A.

is, however, not so good, and exhibits a considerable range of differences depending on R.A.

The Catalogue appears to have been prepared with the care and attention to detail which characterise the work of the Pulkowa Observatory, and will doubtless prove of great value to practical astronomers.

New Edition of Oeltzen's Catalogue of Argelander's Southern Zones.

Professor Weiss has recently published a work that will doubtless prove of great utility to the practical astronomer—viz., a new edition of Oeltzen's Catalogue of Argelander's Zones, extending from 15° to 31° of south declination. The places of the stars situated to the north of 23° south declination have been compared with those given in Schönfeld's *Durchmusterung*, whilst those situated to the south of that limit have been compared with Gould's Cordoba General Catalogue and Cordoba Zones, as well as, in some cases, with the Washington Zone Catalogues, and other Catalogues which furnish positions of stars in that region of the heavens.

In this way a large number of errors in Oeltzen's Catalogue have been found, and Professor Weiss is encouraged to hope that all the errors of any considerable magnitude have been detected and corrected in this edition.

The total number of stars whose places are given in Professor Weiss's Catalogue is 18,276; they are reduced to the epoch 1850·0, and the amount of precession in R.A. and declination to bring the positions up to 1875·0 is also given. In the appendices some interesting information is furnished as to the detection of different classes of errors during the progress of the work, as to the proper motions of a considerable number of the stars, and as to the estimation of magnitudes of variable stars which occur in the Catalogue.

The Photographic Chart of the Heavens.

The second meeting of the Permanent Committee, appointed by the Astrophotographic Congress of 1887, was held at the Paris Observatory on March 31, 1891, and following days.

The following members of the Committee were present:—MM. Baillaud, Bakhuyzen, Beuf, Christie, Denza, Donner, Gill, Paul Henry, Prosper Henry, Janssen, Kapteyn, Lœwy, Mouchez, Pujazon, Rayet, Ricco, Tacchini, and Trépied. The following astronomers were also present by invitation:—MM. Abney, Andoyer, Belopolsky, Bouquet de la Grye, Cornu, Knobel, Gautier, Maturana, Plummer, Scheiner, Tisserand, and Wolf.

Admiral Mouchez gave an address at the opening meeting

recounting the progress that had been made by the various participating observatories since the last meeting of the Committee in September, 1889, and indicating the principal points to which the attention of the Committee would have to be directed.

Drs. Gill and Bakhuyzen were elected Vice-Presidents, and the representatives of each observatory were invited to state how far the photographic installation was complete and to exhibit specimens of the negatives already taken. A small committee was appointed to report upon these exhibits, who found among them a great similarity both as regards the appearance of the stars at the centre and at the edges of the plates; and all admirably suited for promoting the formation of a photographic chart of the heavens.

The more important subjects which occupied the Committee will be gathered by recording the resolutions adopted on each. These resolutions are either important in themselves, or important as effecting a change in the programme arranged at previous meetings.

(*a*) The orientation of the plates taken at a declination greater than 65° will be arranged for the equinox of 1900; for stars of a less declination the parallel will be referred to the apparent equinox.

(*b*) The work undertaken by the Congress of 1887 necessitates two series of negatives, made with different exposures. The Committee, while urging the utmost activity in the production of the plates of shorter exposure, recommends the observers to occupy themselves on those nights when the sky is at its best in the production of the negatives of longer exposure destined for the chart.

(*c*) The negatives from which the catalogue is to be formed shall exhibit two exposures: one showing feebly the images of stars of the eleventh magnitude, the other, separated by a distance of approximately the fifth of a millimetre, twice that exposure.

(*d*) The series of negatives destined to form the chart shall be taken in such a manner that an *even* degree of declination shall be in the centre of the plate. This series shall depend upon a single exposure. Observers may be required for the second series, that in which the degree of declination is *odd*, to take three exposures at the angular points of a small equilateral triangle.

(*e*) The following distribution of the zones among the various observatories was definitely accepted in place of that published in *Monthly Notices*, vol. l. p. 246.

North.			South.		
Greenwich	+90°	+65°	San Fernando	−3°	−9°
Rome	+64	+55	Tacubaya	−10	−16
Catania	+54	+47	Santiago	−17	−23
Helsingfors	+46	+40	La Plata	−24	−31
Potsdam	+39	+32	Rio de Janeiro	−32	−40
Oxford	+31	+25	Cape of Good Hope	−41	−51
Paris	+24	+18	Sydney	−52	−64
Bordeaux	+17	+11	Melbourne	−65	−90
Toulouse	+10	+5			
Algiers	+4	−2			

The political condition of some of the States of South America has rendered uncertain the amount of assistance their respective Governments will be able to accord the scheme.

With the view of preserving and continuing Argelander's scale of magnitudes below the ninth, a sub-committee was formed to select and distribute among the participating observatories metallic screens of fine gauze and of identical structure. It was hoped that when such a screen was placed in front of the photographic object-glass, practically $\frac{5}{6}$ of the incident light would be stopped, and in this manner the appearance and light of a ninth-magnitude star would be reduced to an eleventh, and thus enable observers to determine the proper time of exposure for securing the impression of an eleventh-magnitude star on Argelander's scale. Further, it was proposed that the Paris observers having determined this necessary length of exposure (t), the fraction $\frac{40}{t}$ (in minutes of time) should be the factor for multiplying the length of exposure found necessary to obtain a satisfactory impression of stars of the eleventh magnitude, in order to obtain the proper duration of exposure for the chart plates.

A majority of the sub-committee has, however, found the proposal ineffective in practice, and has recommended its discontinuance; but to ensure the desirable uniformity of magnitude on the Catalogue plates, Professor Pritchard has, with the approval of the President of the Committee, circulated among the various observatories photographs of typical areas on the sky, on which are marked the magnitudes of a certain number of stars on Argelander's scale, determined photometrically at Oxford.

A sub-committee was likewise appointed to report on the method of reproducing the photographs to form the chart. The members, while leaving to each astronomer the choice of details in the method of procedure, recommend that the reproductions shall be effected by photogravure in such a manner as to exhibit black images on a white ground, without the interposition of a

photographic positive. The original negative will be enlarged twice, so that the space between two lines of the *réseau* will be 10 millimetres.

The *Comité International Permanent* has issued a sixth "fascicule" treating of subjects interesting to those engaged in the international chart. The subject of magnitude has, in this "fascicule," received much attention from several experts, and the subject demands still further inquiries. Dr. Scheiner in the *Astronomische Nachrichten*, Professor Pritchard in the *Comptes Rendus*, and the Astronomer Royal in the *Monthly Notices*, have all contributed to the literature of this subject.

Anticipating the appearance of another "Bulletin," M. Loewy has published the details of a scheme having for its object the diminution of the number of fiducial stars required for the reduction of the Catalogue plates by combining the measurements made on contiguous negatives. The Committee appointed to report on the observation and collection of the necessary data recommended that the positions on each plate should be made to depend on the meridian observations of six stars suitably situated on each plate. M. Loewy computes that the full development of such a plan would require the accurate observation of some 60,000 or 70,000 stars which at present do not exist in any catalogue, and these stars would probably be required to be observed twice at two observatories. M. Loewy proposes to make use of the fact that, owing to the plan by which the plates of the second series will overlap those of the first, any star on a plate will be found on one of the four plates which cover the first, so that by a triangulation the four superposed plates can be made available for the reduction of the first. By continuing the process, all the known stars in a space of 36 square degrees can be used to determine the positions of the stars measured on the first plate, and even further combinations, M. Loewy suggests, can be made. In this way a sufficient number of stars, whose places have been accurately determined already, exist for the discussion of the Catalogue plates.

Prominence Photography.

Mr. G. E. Hale, Director of the Kenwood Physical Observatory, Chicago, has made the work of photographing the forms and spectra of prominences the subject of his special attention. His earlier attempts were made upon the C line, some ingenious arrangements of moving slits being devised to give photographs of the complete prominence. Latterly he has, however, turned his attention to the H and K lines, and here a much greater measure of success has attended his efforts.

The spectroscope employed is a large one, and is mounted on the 12·2-inch equatoreal of the Kenwood Observatory. It consists of a 4-inch Rowland grating, ruled with 14,438 lines to the

inch, together with a collimator and telescope, rigidly fixed at an angle of 25° to each other, and each having an aperture of $3\frac{1}{4}$ inches and a focal length of $42\frac{1}{2}$ inches. The spectrum of the fourth order is generally employed.

Early last April Mr. Hale secured the first photograph of the spectrum of a prominence obtained without an eclipse. This showed two very strong bright lines nearly at the centres of the dark solar bands H and K. The same lines were photographed on subsequent occasions, but it was not until June 23 that any new lines were discovered. On this occasion four lines were obtained in the ultra-violet—a number since increased to six. Of these six, five lines belong unmistakably to the series of hydrogen lines discovered by Dr. Huggins in the ultra-violet of the spectra of Sirian stars. The sixth line forms a close double with one of these hydrogen lines (α), but its origin has not yet been accounted for. It would seem from its appearance not to be due to hydrogen, though so frequently in close connection with one of the series. The α line in stellar spectra shows no signs of duplicity, so that this companion line is probably of a different origin.

Professor Young, who has also obtained a considerable number of photographs of the ultra-violet spectrum of the chromosphere, and has, like Mr. Hale, constantly obtained the reversal of the H and K lines, and succeeded in obtaining the first five members of the Huggins series, has failed to detect this companion line to α, a result the more curious since nearly all Mr. Hale's plates which show α show it as double.

Mr. Hale's conclusion that H and K are not due to hydrogen is abundantly confirmed by Professor Young, and also by M. Deslandres, who has been working in the same field at the Paris Observatory with considerable success, since the measures have shown beyond a doubt that the "companion line to H," and not H itself, is the one really due to hydrogen. Mr. Hale and M. Deslandres ascribe these two giant bands of the solar spectrum to calcium, an opinion Professor Young hesitates to accept. If the bright H and K lines are due to calcium, then it would appear from the observations of both Mr. Hale and M. Deslandres that the vapours of that metal rise higher in the solar atmosphere than do those of hydrogen.

In addition to these most noteworthy results obtained already, although this new field has only just been entered upon, both Mr. Hale and M. Deslandres have taken several photographs showing interesting examples of the displacements of chromospheric lines in solar storms. His success in obtaining the reversal of the H and K lines in the spectra of prominences has also induced Mr. Hale to attempt to photograph their forms. For this purpose these lines are especially well adapted, since the presence of the broad dark lines of the solar spectrum enables the slit to be opened wide without too great interference from the atmospheric glare. He has met with considerable

success in this work, some of the photographs showing a satisfactory amount of detail. In one instance a prominence photographed at Kenwood was being sketched by Herr Fényi at Kalocsa at the same moment of time, and drawing and photograph show a close accord. M. Deslandres has also attacked the same problem and proposed that a uniform rotation should be given to the spectroscope, the sensitive plate being at the same time made to travel across the field at the same rate. In this way a complete picture of the entire chromosphere could be readily obtained. A young Englishman also, Mr. Evershed, of Kenley, though with very small optical means, his equatoreal only having an aperture of $2\frac{3}{4}$ inches, and his collimator having a focal length of only 6 inches, has succeeded in obtaining some most creditable photographs of the prominence forms.

The Solar Spectrum at Medium and Low Altitudes.

An important study of the telluric spectrum, due to Dr. L. Becker and published in the *Transactions of the Royal Society of Edinburgh*, has appeared during the year. Its chief feature is a catalogue of 3,637 lines of the solar spectrum, the position and intensity of each of which has been observed a number of times, both with the Sun at a medium elevation and when it is low down on the horizon. To effect a work of such magnitude during such opportunities as two summers afforded would have been quite impossible but for the ingenious recording instrument which Dr. Becker devised and constructed. Its fundamental idea was the magnification of the motion of the grating to such an extent that it could be recorded on a continuous fillet of paper, so that, the viewing telescope being firmly clamped, the exact positions of the grating could be pricked off on the fillet as the lines were successively brought up to the cross-wires in the field of view. This was effected by a system of geared wheels, the first of which had an angular motion 16,800 times as large as that of the grating. The recording-wheel was also turned by this driving-wheel, and the resulting scale on the paper fillet which passed over the recording-wheel was such that the D lines were nearly 20 inches apart, and the entire spectrum mapped—from λ 6024 to F—would require a strip 314 feet long. A set of five prickers arranged across the fillet enabled the observer by using various combinations of them to make 31 different signals. Only 19 were, however, employed, of which 14 were used to indicate the degree of intensity of the lines observed.

The observations were made during the summers of 1887 and 1888, with three days in 1889, from the top of the Barmekin, a hill about 850 feet high in a commanding position about a mile and a half from Dun Echt Observatory. Lord Crawford erected a temporary observing station here and provided it with suitable accommodation for camping out, as Dr. Becker was

generally obliged, owing to the shortness of the summer nights and the distance from Dun Echt, to spend the night at the station.

His instrumental equipment consisted of an object-glass of 6 inches aperture and 7 feet focal length, used in connection with a heliostat to throw the Sun's image upon the slit of the spectroscope. The latter consisted of a Rowland grating of 14,438 lines to the inch, the ruled surface being 5·5 by 3·8 inches, with collimator and view-telescope, both of 4 inches aperture, and fixed at an angle of 25° to each other. The observations were made in the second-order spectrum, and in most cases were obtained on both sides of the normal. Their reduction was most carefully effected, some 260 standard lines being employed, adopted for the most part from Professor Rowland's essay "On the Relative Wave-lengths of the Lines of the Solar Spectrum."

The advance made by Dr. Becker upon our previous knowledge of the details of the telluric bands is very considerable. Except the band by D, popularly known as the "Rain-band," no telluric band in the portion of the spectrum examined by Dr. Becker had been resolved into lines until the appearance of M. Thollon's superb atlas, which was unpublished at the time when Dr. Becker commenced his task. And even as compared with that magnificent work, Dr. Becker has succeeded in recording a very considerable percentage of new lines, both solar and telluric—a result probably due to the superiority possessed by a first-class grating over even so powerful a train of prisms as that employed by the great French spectroscopist.

The chief results arrived at by Dr. Becker is that, with the exception of twenty-eight lines, all the telluric lines in the portion of the spectrum which he has studied are comprised in three bands situated respectively in the regions $\lambda = 6020$ to 5666, $\lambda = 5530$ to 5386, and $\lambda=5111$ to 4981, the two last being Brewster's bands ζ and ι, and that all the darker lines are due to water-vapour. The several bands of the water-vapour lines form a very interesting series, the wave-lengths of the centres of five out of seven being very nearly in harmonic progression. The first of the three groups above mentioned would itself appear to consist of three bands, the first and last being water-bands, viz.: the "Rain-band," and Brewster's band δ, whilst a group of fainter lines, due probably to oxygen, lies between. Band δ would seem to have been ascribed to dry air by Brewster and Angström, but Dr. Becker's observations lead him to ascribe it to water, at any rate as regards its principal lines.

The catalogue contains not merely the mean intensity of the lines with both a high and low Sun, but also the details of the separate observations, 26,107 in number, for the Sun on the horizon, and 8,325 for the Sun at a medium elevation: an addition which may be very useful to later inquirers. A double chart of the spectrum, carefully prepared by Dr. Becker himself, and re-

produced by photolithography, which occupies ten plates at the end of the memoir, exhibits the spectrum as seen at moderate altitudes of the Sun, and the telluric spectrum alone when the Sun is close to the horizon.

The Draper Catalogue of Stellar Spectra.

The Report of the Council for 1888 drew attention to the important work which was then being set on foot at the Harvard College Observatory in furtherance of Mrs. Draper's desire to commemorate the memory of her late husband in the manner most worthy of one who had been so devoted and successful a worker in the new lines of research which the development of the spectroscope and of photography had opened out. For this purpose Mrs. Draper had liberally supplied Professor E. C. Pickering with instruments and funds, and now one most important item of the programme, which Professor Pickering had proposed to himself when he accepted this trust, has been brought to a successful conclusion.

The work proposed in connection with the Draper Memorial was the study of stellar spectra by means of photography, that being the particular research which had most engaged Professor Draper's attention during the last years of his life. And this divided itself into two chief branches: one the formation of a general spectroscopic catalogue, the other the more detailed study of the spectra of the brighter stars. The former work—so far, at least, as it regards the stars from the north pole down to south declination 24°—has been completed, and forms vol. xxvii. of the *Annals of the Astronomical Observatory of Harvard College*, to which it is proposed to give the convenient and appropriate name of "The Draper Catalogue."

The catalogue contains details of the spectra of 10,351 stars, deduced from the measurement of 28,266 spectra—all the stars, in fact, in the region surveyed down to about the seventh magnitude, excepting those of a reddish colour. So great an undertaking could not have been effected in so short a space of time but for three circumstances to which Professor Pickering draws attention—viz., the increased sensitiveness of photographic plates, the use of an object-glass prism instead of a spectroscope of the usual form, and the substitution of a photographic doublet for the usual objective. The advantage of this combination was that it enabled all the stars over a field 10° square to be photographed at once, and with an exposure, in the case of equatorial stars, of only about five minutes.

The instrument employed was a Voigtländer lens of 8 inches aperture and 44 inches focal length, with a prism, 8 inches square and having a refracting angle of 13°, fastened before it, the refracting edge of the prism being parallel to the Equator.

The spectrum of the star formed a line on the plate, and by altering the speed of the driving-clock any desired breadth could be given to the image of the spectrum. The spectra obtained were 0·4 inch in length by 0·04 in breadth. Three or four exposures were usually made upon each plate—a practice which seems open to serious objection, though it of course lessened the cost of the survey. Mrs. Fleming superintended the measurement of the plates and the preparation of the catalogue, being assisted throughout by a staff of ladies.

The volume contains five tables, of which the first is the actual Draper Catalogue. This contains the reference number of each star, its number in the *Durchmusterung* and in the Harvard Photometry, its place for 1900, and the number of photographs obtained of it. Then follow the type of the spectrum and its photographic magnitude, and a table of the differences between this last value and the Bonn, Argentine, and Harvard magnitudes respectively. The types of spectra upon which the classification is based are not precisely those of Secchi, or of any other previous grouping, since certain grades of difference were readily recognised in the part of the spectrum most easily photographed—viz., the violet—which escaped notice in that part which is brightest to the eye. Instead, therefore, of Secchi's four types, no fewer than 16 classes are adopted, which are distinguished by letters of the alphabet.

The classification is, in brief, as follows:—Classes A to D correspond to Secchi's type I. These show Dr. Huggins's hydrogen series of lines as their chief feature. When these lines and the K line alone are seen the star is of class A; if other lines are present, of class B. A doubling of the lines G and *h* denotes class C, and the presence of bright lines, class D. Letters E to L correspond to Secchi's second type, the letter E being used when only the lines F, H, and K are seen, the letter F if the hydrogen lines are visible, and the letter G if other lines are seen as well. Different changes in the intensity of the continuous spectrum are grouped under the letters H, I, K, and L. The third type is indicated by the letter M, the fourth by N, bright-line stars by O, planetary nebulæ by P, and stars not comprised under any of the previous heads by Q.

The "photographic magnitude" which follows the spectrum-type is an attempt to determine the brightness of stars on a new principle, for instead of the *total* light of the stars being compared, only the light of a particular wave-length, near the G line, is taken. On this plan the relative magnitude of any two stars should always be the same, whether observed directly by the eye, or by photography, or by the bolometer. It is, therefore, the inauguration of a new system of photometric comparison, which may possibly prove of great importance hereafter. In the meantime an immense amount of material for future discussion is accumulated here.

Following the catalogue proper is a second table, containing

certain details of the measurements of the spectra, in particular the "photographic magnitude" of each star as deduced from the several plates on which it appears, the intensity of the F and K lines in its spectrum, and the distance in the ultra-violet to which the hydrogen series of lines can be traced. Further details are supplied in the "Remarks," which occupy 112 pages, so that the catalogue contains much more than the mere assignment of each star to its proper type; a great amount of additional information is also given.

Other tables contain a list of the types of spectra of Bayer's stars, and of the numbers of stars observed in each hour of R.A.

The discussion of the vast mass of material here brought together is reserved for vol. xxvi. of the *Annals*. Yet several interesting results appear on the surface. The insufficiency of Secchi's types when applied to the photographs of stellar spectra, the possibility and even the necessity of a minuter classification, when the violet and the ultra-violet regions are examined, than when the spectra are viewed directly by the eye, are important conclusions. Comparisons of the Draper Catalogue with those of Vogel and von Konkoly show also that the visual type is not an unerring guide to the photographic, and *vice versâ*. A further point of interest to which Professor Pickering has drawn attention is the predominance of stars of Secchi's first type in the Milky Way, a circumstance which must be of much importance in any theory as to the nature and formation of that ring.

Strassmaier and Epping's Researches on Babylonian Astronomy.

It was in the year 1881 that Fathers Strassmaier and Epping first began their joint labours on this almost unknown branch of science, Father Strassmaier deciphering the Assyrian texts, and his colleague submitting them to mathematical analysis, thereby suggesting new readings and the meanings of unknown words. The result has been that they have established in great measure the system of the astronomy of the Babylonians, and not merely the translation of a few odd texts. The work so far accomplished—and it is still progressing—embraces the thorough understanding of their method of calculating and predicting the new Moon, the establishing of the dates of the era of the Seleucidæ in Julian style, the explanation of their lunar and planetary calendars, and the mode of prediction used therein, as also the publication of several lunar and planetary tables of observation: one of the lunar eclipses thus brought to light being, as Dr. Oppert has pointed out, one of the nine used by Ptolemy in the *Almagest*. The papers published by Fathers Strassmaier and Epping have appeared in the *Stimmen aus Maria Laach*, since 1881; as also in the *Zeitschrift für Assyriologie*, 1890, pp. 281 *et seq.*, pp. 341 *et seq.*; 1891, pp. 89

et seq., and pp. 217 *et seq.* They also published in 1889 a work entitled *Astronomisches aus Babylon, oder das Wissen der Chaldäer über den gestirnten Himmel.* The chief results so far obtained may be thus summarised:—

1. *Tables of Calculation.*—These contain a complete method of calculation for the determination of the new Moon, comprising the calculation of the time by which the last crescent visible before conjunction precedes the rising of the Sun, the determination of the new Moon, and the calculation of the interval of time between new Moon and first crescent. As an example of the method we may take the following from the columns called by Epping b, c_1, c_2, d, and e of the Table A, denoting by Roman numerals the different horizontal lines. We must first premise that they divided the day into 360° of time, as appears from these tablets, each degree being divided by 60 and 60. Suppose, then, knowing the date and instant of true new Moon for the Month I., they wanted to pass to that of II. The process may be thus represented:—$\text{II}.e = \text{I}.e + \text{II}.d$; while $\text{II}.d = \text{II}.\,b \pm \text{II}.\,c_2$, or $= \text{II}.\,b \pm \text{I}.\,c_2 - \text{II}.\,c_1$. Column b has its terms in A.P., common ratio 22° 30′ (of time); likewise column c_1, common ratio 6° 47′ 30″. Column b then contains the term necessary to add to twenty-nine days to pass from one conjunction to the next, after correction by c_1 and c_2, which take account of the term depending on the motion of the true Sun. It follows from these tables that they had a remarkable knowledge of the mean duration of the synodic and anomalistic months, the former differing by only half a second from Hansen's value for 1800 A.D., and the latter by one-and-a-half seconds. Another column of figures shows that they knew the mean velocity of the Moon, and consequently the sidereal month. It is not quite clear that they were able to distinguish the different kinds of years; but they had a very approximate knowledge of the maximum velocities of Sun and Moon, as also of the law of variation of the velocity of the Sun at the different epochs of the year. As a confirmation of the truth of Epping's results, we may remark in passing, that he has actually succeeded in constructing a column for one table to which an exactly corresponding column was found in another table, as also in giving the true reading for a damaged column.

2. *Chronological Results.*—The commencement of the eras of the Seleucidæ (S.E.) and of the Arsacidæ (A.E.) have been fixed with a certainty which is based upon the calculation of eclipses contained in the Lunar Calendars. The years of the Seleucidæan era were luni-solar; their months lunar, sometimes of thirty, at others of twenty-nine, days. They employed intercalary months, but according to what law is yet unknown. The year commenced with the month Nisan, which fell about the spring equinox. The five following dates have been determined by Father Epping:—

1 Nisan	188 S.E.	= April	4 − 123	J.E.
„	189 „	= March	25 − 122	„
„	190 „	= April	12 − 121	„
„	201 „	= „	10 − 110	„
„	202 „	= March	30 − 109	„

Hence the Seleucidæan era began in the year −310 of the Julian era, and that of Arsacidæ in the year −246. The civil day of the Babylonians began at sunset, and the division of the day into twenty-four hours was in use amongst them. But their astronomers, as is evident from the calculating tables, besides using a division of the day into 360 time-degrees, referred its commencement to the midnight following the beginning of the civil day.

3. *Lunar Ephemerides.*—An example may be that for the month Nisan of the year 189 S.E.:

1	20	30	tab.	13	9		na.
12	1	10	shu.	14	8	30	mi.
13	8	4	me.	26	15		mat.

Six phenomena are predicted for each month, one for the beginning, four about the middle, and one for the end of the month. Predicted—for were these indications observations, their astronomers must, unlike any others, have been blessed with fine weather at almost stated intervals every month. But, a stronger argument, there are five errors of position in the tables, which, if the indications are observations, would compel us to believe that their astronomers affirmed they saw the Moon above the horizon when it was below. The first and last phenomena predicted are the times measured in time-degrees along the equator or the ecliptic—for this point is still unsettled—during which the first crescent will remain above the horizon, and during which the last crescent will remain visible before disappearing in the Sun's rays. The other phenomena relate, two of them to settings of the full, or nearly full, Moon, one of which will precede and the other will follow sunrise; the other two to risings of the full, or nearly full, Moon under the same conditions.

These tables also contain predictions for five eclipses of the Sun and five of the Moon, with their conditions of visibility at Babylon. As an example of their correctness we may take that of the Moon predicted for the 15 Ijar 201 S.E. at $1^t\ 1^\circ$ before the rising of the Sun, of magnitude 5, and visible at Babylon. According to Epping the prediction is for the year −110 J.E., May 23, $7^h\ 20^m$. Oppolzer's Canon gives an eclipse, magnitude 4·5, visible at Babylon for May $23^d\ 7^h\ 22^m$ of this year.

4. *Planetary Ephemerides.*—By means of these tables the authors have been able to give the Assyrian names, or ideograms,

for all the planets. For instance, the name which occurs most frequently is *gut-tu*, which Assyriologists hitherto always translated as *Jupiter*. But *gut-tu* is *Mercury*, a planet the observations of which seem to have been very important for their astronomers. Their method of fixing the positions of the planets, was by drawing a series of lines as perpendicular as possible to the ecliptic, through sets of couples of bright zodiacal stars. The time when the planet would pass such a line, and its distance above or below a bright star, are the time and place predicted and observed. They also predicted the oppositions and stationary points of the planets, as well as their heliacal risings and settings. The oppositions and heliacal risings and settings of *Sirius* are also predicted. Hence we learn the names of twenty-eight stars and a good number of constellations. The astronomical seasons are also determined on these tablets. Moreover, they knew the periodic times of the planets, and used systematic compilations of observations to predict future ephemerides.

A great deal of material still remains to be thoroughly discussed by the authors, which, we may hope, will be as fruitful in results as their past labours have led us to expect. These observations of 2,000 and more years ago, especially those of the Moon, which seem to have been made with the greatest care and exactness, may possibly prove of service in the correction of modern tables. A. L. C.

The British Astronomical Association.

The British Astronomical Association was founded during the autumn of 1890 as an association of amateur astronomers for the United Kingdom, and more especially for those who, from one circumstance or another, might be precluded from joining the Royal Astronomical Society. It thus included ladies, of whom many take an interest in the science and have contributed to its progress.

That the Association met an acknowledged want was proved by the rapidity with which the names of those desirous of joining it were sent in. By October 18, 1890, when the first general meeting was held, 283 members had already joined, and by the end of the first session 584 members had been enrolled, there being at the present time considerably over 600 members, including 30 ladies.

Although the Association was intended primarily for the United Kingdom, of the 584 members who had joined during the first session, 33 are resident in the United States or Canada, 2 in Mexico, 2 in South America, 8 in India, 19 in Australia and New Zealand, 11 at the Cape of Good Hope, and 3 in China and Japan; and most of the well-known astronomical societies are represented amongst the members of the new Association.

The great object of the Association being the organisation of amateur observers for mutual help in suitable departments of observation, a leading feature of the Association has been the establishment of sections, under the guidance of competent and experienced directors, for the observation of various classes of objects and celestial phenomena. There are now eleven sections for the observation of the Sun, Moon, planets, solar and stellar spectroscopy, variable, coloured, and double stars, comets, and meteors, as well as a photographic section.

Several of these sections, in the work of which over 100 of the members are associated, have already done good systematic work.

The *Journal* of the Association, under the able editorship of Mr. E. W. Maunder, is a model of what such a publication should be, and has contributed not a little to the success of the Association. A. C.

Telegraphic Determination of Longitudes in Mexico, Central America, the West Indies, and on the North Coast of South America, 1888–89–90.

In 1883 the Bureau of Navigation of the United States Navy commenced a systematic determination of secondary meridians by telegraphic measurements of the differences of longitude. The plan was to work from Galveston in Texas, down the Gulf of Mexico, and thence down the west coast of Central and South America to Valparaiso. In 1885 a report* of the portion of the work then accomplished was published. The difficulties to be overcome in completing the portion between Vera Cruz, on the Gulf of Mexico, and La Libertad, on the Pacific Coast of Central America, caused this to be postponed. It was, however, taken up again in 1888, and the work of the expedition forms the text of the present publication. The following is a list of longitudes and latitudes determined by this second expedition :—

	Longitude West			Latitude North		
	h	m	s	°	′	″
Coatzacolcos (Lighthouse)	6	1	39·11	18	8	56·3
Salina Cruz (Summit of Morro de Salinas) ...	6	20	49·07	16	9	35·9
La Libertad (Iron Wharf)	5	57	17·29		...	
San Juan del Sur (Signal Station) ...	5	43	31·97	11	14	44·6
St. Nicholas Mole (Fort St. George) ...	4	53	32·45	19	49	15·1
Port Plata (Lighthouse)	4	42	45·77	19	48	50·8
Santo Domingo (Lighthouse)	4	39	31·95	18	27	53·6
Curaçao (Rif Fort Lighthouse)	4	35	45·82	12	6	20·1
La Guayra (Lighthouse near Breakwater) ...	4	27	44·37	10	36	57·4

* This was noticed in the *R.A.S. Report*, 1886, February.

The equipment of the expedition was very complete, and, at the suggestion of the hydrographer, Lieutenant Dyer, a set of instruments for magnetic observations, consisting of a magnetometer and dip circle, was included in the outfit.

The transits were of 30 inches focal length and $2\frac{1}{2}$ inches aperture. The eyepiece was at the end of the axis, so that the observer always retained the same position. On the former expedition the spider-line reticules met with so much injury in transportation that it was decided to use ruled-glass diaphragms. Seven wires were used for transits. The chronographs were of the cylinder type, light and easily adjusted. Each party also carried a Siemens polarised ink-writer, which was found exceedingly useful as a telegraph instrument, a chronograph, and a polarised relay where the feeble current demanded an extremely delicate relay. It is practically what in the recent Paris longitude work was known as 'the table.' A pier of brick and cement, 24 inches by 22, and 36 inches high, was built at each station. Longitude work was generally commenced between seven and eight in the evening, the telegraph lines being free after eight o'clock. Five or six time stars would be observed, and two or three polars, when the instrument was reversed and a similar set taken. The line-connections were made so that the chronograph at one station would register its beats on its own cylinder and on that of the distant station simultaneously. For latitude work pairs of stars were selected within 25° of the zenith, the stars of each pair not differing more than 20′, and ranging from 2^m to 15^m in R.A.

No corrections were made for personal equation. It was impracticable to exchange observers, owing to the conditions of transport. The best thing, under the circumstances, appeared to be to locate the observers alternately east and west of each other, thus diminishing, if not eliminating, the P.E. at every second station.

The method of reduction was that always employed in American longitude work. The collimation, level, and azimuth obtained in the ordinary way were used as approximate values to reduce the observations. These corrected observations, after the application of diurnal aberration, hourly rate, inequality of pivots and flexure, furnished equations of condition for the final reduction to determine the correction to assumed errors. These equations were solved by the method of least squares. The hourly rate was obtained graphically—a process well suited to this class of observation. The observations are given in detail, and at the end of each night are the resulting normal equations. In addition to giving the figures of the resulting longitudes and latitudes, large-sized charts are appended for easy identification of the sites of the piers, &c.

The unifilar magnetometer and the dip circle were set up at each station. The constants and corrections were carefully

obtained, and, as in the previous work, given in great detail. The following table shows the results:—

Locality	Date	Declination East	Dip.	Horizontal Intensity (British units)
		° ′	° ′	
Vera Cruz, Mexico	Dec. 1888	7 13	44 20	...
Coatzacoalcos, Mexico	Feb. 1889	6 53	43 3	7·2890
Salina Cruz, Mexico	Mar. 1889	6 59	40 2	7·4300
Port Plata, San Domingo	Dec. 1889	0 37	49 50	6·6667
Curaçao, W. Indies	Jan. 1890	2 28	39 13	6·9841
La Guayra, Venezuela	Feb. 1890	2 51	37 35	6·9496

The value of the work becomes naturally enhanced from the fact of being the connecting-link between the two portions previously done.

T. L.

Papers read before the Society from February 1891 to January 1892.

1891.

Mar. 13. Ephemerides of the satellites of *Uranus*, 1891. A. Marth.

Ephemeris for physical observations of the Moon, 1891, Feb. 12 to May 5. A. Marth.

On the determination of double-star orbits from spectroscopic observations of the velocity in the line of sight. A. A. Rambaut.

The Companions of *Aldebaran*. S. W. Burnham.

Catalogue of 918 orbits of meteor streams, from the observations of Mr. W. F. Denning. J. Kleiber.

Mean places of comparison stars for the planets *Victoria* and *Sappho*, observed with the Cambridge transit-circle. Communicated by Professor J. C. Adams.

Observations of the satellites of *Saturn*: conjunctions with the centre of the planet, observed at Mr. E. Crossley's Observatory, Bermerside, Halifax. J. Gledhill.

Observation of the variable star S (10) *Sagittæ*. J. E. Gore.

The orbit of κ *Pegasi* (β 989). S. W. Burnham.

Measures of double stars made at Sydney Observatory in the years 1882–89. Communicated by H. C. Russell.

Comparison of the star-places of the Greenwich Ten-year Catalogue with those of the Second Melbourne General Catalogue, and with those of the Cape Catalogue for 1880. A. M. W. Downing.

Double-star measures, made at Windsor, New South Wales, 1889 and 1890. John Tebbutt.

Note on the orbit of *Juno*. A. M. W. Downing.

Ephemeris for physical observations of *Jupiter*, 1891. A. Marth.

Observations of the planet *Victoria* and comparison stars, made with the transit-circle of the Radcliffe Observatory Oxford, during the opposition of 1889. Communicated by E. J. Stone.

Notes on the preparations for the Astro-photographic Chart at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Mar. 13. Variations of latitude deduced from the observations of *Polaris*, made at Greenwich, 1851–89. Professor H. G. van de Sande Bakhuyzen.

Note on the parallax of β *Aurigæ*. Professor C. Pritchard.

Apr. 10. *Sirius*. S. W. Burnham.

Observations of phenomena of *Jupiter's* satellites, made at Windsor, New South Wales, in the year 1890. John Tebbutt.

Reduction of measures of the photographs of *Jupiter*, taken at the Lick Observatory in 1890. A. Stanley Williams.

Sur la détermination récente de la longitude Paris-Greenwich. Col. Bassot and Commandant Defforges.

On the recent determination of the longitude Paris-Greenwich; reply to Colonel Bassot and Commandant Defforges. H. H. Turner.

On the orbit of the periodic Comet 1867. I. Dr. Ludwig Becker.

Invisible double stars. S. W. Burnham.

A comparison of the north polar distances of the *Nautical Almanac* for 1880 with the Cape Catalogue, the Greenwich Ten-year Catalogue, and Boss's Standard Star places for 1880. W. G. Thackeray.

Approximate proper motions of certain Groombridge stars. W. G. Thackeray.

The perturbations of *Sappho* (80). R. Bryant.

Ephemeris for physical observations of the Moon, 1891. A. Marth.

May 8. On the character of the chief line of the nebula in *Orion*. K. D. Naegamvala.

Photograph of *Neptune* and its satellite. Isaac Roberts.

Photograph of the region of Hind's variable nebula in *Taurus*. Isaac Roberts.

Photograph of the cluster 44 M *Cancri* (the *Præsepe*). Isaac Roberts.

Further experience regarding the magnitude of stars, as obtained by photography at the Oxford University Observatory. Professor C. Pritchard.

On a new dome to be erected at the Royal Observatory, Greenwich. W. H. M. Christie.

June 12. Notes on some star photographs recently taken at the Sydney Observatory. No. 2. H. C. Russell.

The Companions to *Regulus*. S. W. Burnham.

Probable early observation of an immersion of *Titan*. Rev. S. J. Johnson.

June 12. On the transit of *Mercury*, 1891 May 9, as seen at Daba Gardens, Vizagapatam. A. V. Nursingrow.

Observations of the transit of *Mercury*, 1891 May 9. K. D. Naegamvala.

Proper motions of twenty southern stars. Dr. J. L. E. Dreyer.

A method of photographing the invisible solar prominences. G. E. Hale.

Photographs of the metallic spectra. Frank McClean.

Observations of the Moon, made at the Radcliffe Observatory, Oxford, during the year 1890, and a comparison of the results with the tabular places from Hansen's Lunar Tables. E. J. Stone.

Observations of the partial solar eclipse of 1891 June 6, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Data for computing the positions of the satellites of *Jupiter*, 1891; with tables of the inequalities. A. Marth.

Ephemeris for physical observations of the Moon, 1891. A. Marth.

Observations of the transit of *Mercury*, 1891 May 9, made at the Royal Observatory, Edinburgh. Dr. R. Copeland.

The orbit of 36 *Andromedæ* (Σ 73). T. Lewis.

Preliminary note on the change of personal equation with stellar magnitude in transits, observed with the transit-circle at the Royal Observatory, Greenwich. W. H. M. Christie.

Nov. 13. The transit of *Mercury*, 1891 May 9, observed at Sydney Observatory. Communicated by H. C. Russell.

The motion of 20 *Draconis*. S. W. Burnham.

Observations of the transit of *Mercury*, 1891 May 10. W. J. McDonnell.

Observations of the conjunction of *Venus* and *Jupiter*, 1891 April 7. John Tebbutt.

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Note on the first satellite of *Jupiter*. E. E. Barnard.

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Nov. 13. Ephemeris of the satellite of *Neptune*, 1891–92. A. Marth.

Ephemerides of the satellites of *Saturn*, 1891–92. A. Marth.

On the orbit of Spitaler's comet (vii. 1890). Lieut.-Gen. J. F. Tennant.

On the determination of azimuth by elongations of *Polaris*. H. Jacoby.

Colour changes in the markings on the surface of the planet *Jupiter*. E. E. Barnard.

Observations on the spots and markings on the planet *Jupiter*, made with the 12 inch equatoreal of the Lick Observatory. E. E. Barnard.

On the determination of a certain class of inequalities in the Moon's motion. E. W. Brown.

Measures of planetary nebulæ made with the 36-inch equatoreal of the Lick Observatory. S. W. Burnham.

Corrections and additions to the observations of *Sirius*. S. W. Burnham.

Mean areas and heliographic latitudes of Sun-spots in the year 1890; deduced from photographs taken at Greenwich, at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

Observations of Wolf's periodical comet (*b* 1891). Communicated by the Astronomer Royal.

On new forms of levels. H. H. Turner.

On the supposed duplicity of the first satellite of *Jupiter*. A. Stanley Williams.

Double-star measures, 1888–91. W. H. Maw.

On the reduction of transit observations by the method of least squares. H. Jacoby.

Re-appearance of *Saturn's* ring. Rev. A. Freeman.

A note on some photometric experiments connected with the application of the law of limiting apertures to small object-glasses. E. J. Spitta.

Comparative photographic spectra of the Sun and the metals, series I.–II. Frank McClean.

Ephemerides of the satellites of *Saturn*, 1891–92. A. Marth.

Note on some photographs of *Jupiter*, taken with the 5-foot reflecting telescope. A. A. Common.

Note on the Lunar Theory. Professor A. Cayley.

Dec. 11. The motion of Σ 2525. S. W. Burnham.

Observations of Comet Barnard, 1891, made at Sydney Observatory. Communicated by H. C. Russell.

On the close conjunction of *Venus* and *Jupiter*, 1892 Feb. 5–6. A. Marth.

Dec. 11. Note on the Stonyhurst drawings of solar spots and faculæ. Rev. W. Sidgreaves.

Secular perturbation of the Earth's orbit by *Mars*. R. T. A. Innes.

Observations of Comet Encke, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Observations of Comet *b*, 1891 (Wolf), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the spectrographic method of determining the velocity of stars in the line of sight. Professor H. C. Vogel.

Note on some apparently variable nebulæ. Dr. J. L. E. Dreyer.

Note on the variability of Es-Birm. 973 = D.M. + 39°, 4208. Rev. T. E. Espin.

On the verification of the expressions given in Delaunay's Lunar Theory by a direct differentiation and substitution in the differential equations. E. J. Stone.

On the distribution of temperature in the transit-circle room at the Royal Observatory, Greenwich. H. H. Turner.

On the construction of a 5-foot equatorial reflecting telescope. A. A. Common.

1892.
Jan. 8. Re-appearance of *Saturn's* ring, and position-angle before the disappearance, observed at the Observatory, Utrecht. Professor J. C. Oudemans.

Observations of occultations of faint stars during the total eclipse of the Moon on 1891 Nov. 15. Communicated by Dr. D. Gill.

On the observations for coincidence of the collimators through the cube of the transit-circle at the Royal Observatory, Greenwich. H. H. Turner.

On the phenomena of the transit of the first satellite of *Jupiter*, and observations of the red spots on the planet. E. E. Barnard.

Observations of the phenomena of *Jupiter's* satellites, &c., in 1891, made at Mr. E. Crossley's Observatory, Bermerside, Halifax. J. Gledhill.

On the dynamics of the Earth's rotation with respect to the periodic variations of latitude. Professor S. Newcomb.

Observations of the total eclipse of the Moon, 1891 Nov. 15, at Edinburgh. Dr. R. Copeland.

A new photographic photometer for determining star-magnitudes. W. E. Wilson.

Observations of double stars, made at Mr. E. Crossley's Observatory, Bermerside, Halifax. J. Gledhill.

Jan. 8. The red stars in the great *Perseus* clusters. Rev. T. E. Espin.

On the investigation of the division errors of the scales of the Repsold measuring apparatus at the Cape Observatory, and the determination of the errors of the Oxford *réseau*. Dr. D. Gill.

Ephemerides of the satellites of *Saturn*, 1891–92 (continued). A. Marth.

On the relation between diameter of image, duration of exposure, and brightness of object in photographs of stars taken at the Royal Observatory, Greenwich. W. H. M. Christie.

Observations of occultations of stars by the Moon and of phenomena of *Jupiter's* satellites, made at the Royal Observatory, Greenwich, in the year 1891. Communicated by the Astronomer Royal.

Note on some values of the Sun's mean horizontal parallax which have been deduced from the Transit of *Venus* observations made in 1882. E. J. Stone.

Ephemeris of *Juno* near the time of opposition, 1891, from the corrected elements published in *Monthly Notices*, vol. l. page 495. Communicated by the Superintendent of the *Nautical Almanac*.

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ADDRESS

Delivered by the President, Lieut.-Gen. J. F. Tennant, on presenting the Gold Medal to Professor G. H. Darwin.

THE COUNCIL has this year awarded the Gold Medal of the Society to Professor G. H. Darwin "for his work on Tides and their influence on the Figures and Motions of the Heavenly Bodies," and I have now to lay before you the grounds on which this award has been made.

It is some fifteen years since Professor Darwin commenced his researches into the history of the Solar System, and the striking character of some of his results has already modified so fundamentally our ideas of the course of planetary evolution that it may be well to recur for a few moments to the state of our existing knowledge before these investigations were undertaken. And fortunately Professor Darwin has left on record * a general but explicit statement of the problem or problems which presented themselves to his mind at a time (1877) when he was almost deterred from attempting their solution by the profundity of the mathematical difficulties involved. Looking back with him to this time, we may well admire the determination which has so persistently overcome not only these difficulties, but that of incessant personal ill-health. The Society is glad to welcome as its Medallist one so worthy the name of Darwin as to have worked, under circumstances where most men's energies would have flagged, at the theory of Planetary Evolution.

"The Nebular Hypothesis," to quote the words of our Medallist in 1877, "seems to contain no explanation of the diversity which the telescope shows us is to be found in the inclinations of planets to their orbits," for as the planets "were originally parts of the great solar nebula, there appears to be no reason why the axes about which they rotated should not be nearly parallel to the axis of rotation of the Sun." The explanation of the large inclinations of planetary axes must, therefore, be sought in some feature of their history not considered in the Nebular Hypothesis as far as it was developed by Laplace. It is this second chapter in the hypothesis which Professor Darwin's work supplies, though others doubtless remain to be written.

* *Phil. Mag.*, 1877 March; *Observatory*, vol. i., p. 13.

His first tentative suggestion for the origin of large obliquities was as follows:—The contraction of a rotating planet, from the nebulous stage downwards, involves an increase in the angular rotation, and thus a greater equatorial bulging. Now, the phenomena of precession depend on the attraction of the Sun, and of satellites on the equatorial protuberance and on the rotation; and if these latter are both increased as above, the obliquity of the axis will increase. The obliquity is, in fact, for a given planetary system, dependent merely upon the density, and has increased as the planet has consolidated from a nebula into a compact mass. The mathematical expression of this fact is

$$\text{Log tan (obliquity)} = A - \frac{B}{\text{density}},$$

where A and B are two constants depending on the particular planetary system.

In recent times, therefore, even long before the geological epoch, the obliquity of the Earth's equator to the ecliptic cannot have seriously changed, for its mean density has remained nearly constant. A possible reason for qualifying this statement had been already * examined by Professor Darwin, and found insufficient—viz., that geological changes, such as the elevation of continents, do not conform to the law of contraction by cooling above considered. In the deduction of the above law connecting obliquity and density, the surface of the contracting spheroid has been assumed to be one of equilibrium; but when the Earth has so far contracted as to reach the geological epoch, the surface begins to wrinkle into continents and oceans, mountains and valleys. Professor Darwin's first important paper on planetary history had been devoted to the investigation of the influence of such changes on the Earth's axis of rotation, and though the paper has many other points of interest, it cannot now be referred to further than to quote the principal conclusion in the author's own words: † "If a chain of mountains or a tableland, many degrees in width and as high as the Himalayas, were to be slowly elevated all round the equator, the effect would be *pro tanto* the same as an increase in the compression of the earth—that is to say, to increase the obliquity of the ecliptic. Nevertheless, the effect in that direction of even so gigantic a change would merely be to cause the Arctic circles to approach the tropics by a few inches. As, then, such an elevation is far in excess of any which geology teaches us can have ever taken place, we are compelled to believe that the obliquity of the ecliptic has remained sensibly constant throughout geological history," as it would if the surface had remained one of equilibrium.

We can thus infer from the above formula and our present

* *Phil. Trans.*, 1877, part i.

† *Obs.*, vol. i., p. 15.

knowledge of the obliquity of the axis and density of the earth what was the obliquity when its density was half or a tenth of the present, or when the matter composing the earth was more diffused still. But there are two difficulties. Firstly, the above formula was deduced by arguments applicable to the precession of rigid bodies; and it yet remains to examine how far it will apply on reaching a stage in the past history when the planets were fluid or nebulous. Secondly, as we follow the history backwards, and the earth increases in size with diminution of density, there comes a stage when its surface reaches the Moon; and after this the two must be considered as one body. Before this the precessional effects will depend on the Sun and Moon conjointly, but after this on the Sun alone, and there is thus a discontinuity in the solution of the problem. But "in making a numerical application to the case of the Earth, it is found that the change in the obliquity must have proceeded so very slowly that even *when the earth was so diffuse as to fill the lunar orbit* the obliquity of the ecliptic must have had nearly its present amount." * Pushing back the argument beyond this point (which is characterised by the author as a somewhat wild speculation) it is found that when the Earth's diameter was a thousand times as great as it is at present, the obliquity was only a few minutes of arc.

Attention is called to the phrase printed above in italics because the conditions under which the Moon separated from the Earth were subsequently found by Professor Darwin to be so different; and I shall presently have to refer to this point as one of the most important results in his work.

Returning now to the history of changes in obliquity, and having disposed of the difficulty about the satellites of the other planets in a manner similar to that for the Moon and Earth, the question remains how far the formula for a rigid body is applicable to the history of non-rigid bodies. If it be applicable, then a study of the constants involved shows that the obliquities of the planets should decrease with distance from the Sun, which is not supported by observed facts; and it is thus probable that on taking account of the want of rigidity, fluidity, or nebulosity of a planetary mass we should find a different general result. The continuous alterations in form to which the yielding matter composing the planet would be subjected by the attraction of external bodies may be called bodily tides; and the problem may be regarded as the study of tides in the most general sense of the word. To this extension of our knowledge of planetary history beyond the limitation to the case of rigid bodies Professor Darwin has accordingly applied himself, with a success which the Council of the Society recognises in the present award, and which I will endeavour to describe to you.

The history of a planetary system may be traced in either

* *Obs.*, vol. i., p. 16.

direction, forwards or backwards in time. We may commence with a rotating and slowly contracting nebula, examine the conditions of its stability, and those under which a ring or satellite will detach itself when the stability breaks down, and follow the changes of the multiple system under the influence of gravitation. This is no doubt the ideal method of considering the question. But the generality of this problem, and the mathematical difficulties of dealing with fluids and gases, place it beyond the range of possible solution in practice. Professor Darwin has, however, recently considered * a particular case of the problem from this point of view—viz., that of a rotating fluid ellipsoid which becomes so elongated as to be unstable.

The other method of considering planetary history is to take an existing system, such as that of the Earth and the Moon, and trace its history backward. This has two great practical advantages. Firstly, although, as we have seen, perfect rigidity is inadmissible, the bodies can be treated as approximately rigid, which simplifies enormously the mathematical formulæ involved; and secondly, the general case can be at any time limited by the insertion of known numerical values for the arbitrary constants which present themselves. In this latter connection it is obviously advantageous to select as our particular case that of the Earth and Moon, where we have a far more complete knowledge of the numerical constants than in the case of other planets. Even in this instance, however, our knowledge is found to be lamentably deficient. Professor Darwin is often compelled to be content with a rough and even avowedly faulty assumption in the absence of numerical data, and accordingly some of his conclusions must be received with caution until these deficiencies can be supplied; and although his results have been occasionally quoted in an absolute form which he would be the first to disapprove, a reference to the original papers will always show clearly how far such general statements must be qualified.

If, in what follows, similar omissions of the necessary qualifications are occasionally found, the necessary brevity of this summary must be the excuse.

The work of our Medallist in solving the problem here indicated is to be found chiefly in five memoirs read to the Royal Society:

(1) "On the Bodily Tides of Viscous and Semi-elastic Spheroids, and on the Ocean Tides upon a yielding Nucleus." †

(2) "On the Precession of a Viscous Spheroid, and on the Remote History of the Earth." ‡

(3) "Problems connected with the Tides of a Viscous Spheroid." §

* *Phil. Trans.*, 1887, and *Proc. R. S.*, 1886.

† *Phil. Trans.*, 1879, pt. i.

‡ *Ibid.*, 1879, pt. ii.

§ *Ibid.*, 1879, pt. ii.

(4) "On the Secular Changes in the Elements of the Orbit of a Satellite revolving about a tidally distorted Planet." *

(5) "On the Tidal Friction of a Planet attended by several Satellites, and on the Evolution of the Solar System." †

The first of these papers, "A necessary first chapter to the investigation of the precession of imperfectly elastic spheroids," deals with the forced oscillations, first of a viscous, and ultimately of an elastico-viscous sphere. Sir W. Thomson had already treated the problem of a perfectly elastic sphere, and Professor Darwin shows how his solution may be extended to the case of a viscous sphere, and next of a sphere whose elasticity is not perfect but breaks down under continued stress, the forces requisite to maintain the body in any strained configuration diminishing in geometrical progression as the time increases in arithmetical progression. As an illustration of the necessity for caution in accepting the conclusions, I may quote Professor Darwin's words as to this assumption made at the very outset of the investigation. "There can be no doubt that all bodies *do* possess an imperfection in their elasticity of this general nature, but the exact law here assumed has not, as far as I am aware, any experimental justification; its adoption was rather due to mathematical necessities than to any other reason." If, then, we admit this assumption, it is shown how the problem in an imperfectly elastic sphere may be deduced from that in an elastic sphere. I need not further dwell upon the form of the solution, but a result obtained incidentally in the course of the work is of considerable practical interest. The author digresses from the main problem to consider the *ocean* tides on a nucleus such as we have considered. If there were two bodies precisely similar in form to the Earth, one of which was absolutely rigid except for the water on its surface, and the other composed of yielding matter, the apparent tides on these two bodies would differ, although the shape of the actual surface of the ocean on both might conceivably be the same, for the apparent tide in the first would be measured by the total displacement of the water, while in the second it would be the difference between the displacements of the water and the land. The failure of the observed ocean tides to agree with their theoretical values for a rigid nucleus will thus give an indication of the want of rigidity of the Earth's nucleus; and by a numerical interpretation of his equations Professor Darwin finds that unless the viscosity of the Earth were very much larger than that of pitch at near the freezing point, when it is hard, apparently solid and brittle, the viscous sphere would comport itself sensibly like a perfect fluid, and the ocean tides would be quite insignificant. It follows, therefore, that no very considerable

* *Phil. Trans.*, 1880, pt. ii. † *Ibid.*, 1881, pt. ii.

portion of the interior of the Earth can even distantly approach the fluid state.*

This conclusion as to the great rigidity of the Earth is confirmed several times in the course of Professor Darwin's work, and especially in a paper read to the Royal Society in 1881, "On the Stresses caused in the Interior of the earth by the Weight of Continents and Mountains,"† of which only the principal conclusion can here be quoted—that "if the Earth be solid throughout, then at a thousand miles from the surface the material must be strong as granite. If it be fluid or gaseous inside, and the crust a thousand miles thick, that crust must be stronger than granite, and if only two or three hundred miles in thickness, much stronger than granite."‡ Again, in the second paper quoted above, to which reference will immediately be made, another confirmation is deduced from the theory of the tides. It had been pointed out some twenty years before by Adams and Delaunay that there was an outstanding secular acceleration of the Moon's mean motion of some 3″ per century which could not be explained by ordinary lunar theory. It was suggested that the effects of *ocean* tidal friction might be responsible for this acceleration. The idea of friction of the ocean as held back by the Moon, against the solid Earth rotating inside it, was already familiar; as also the theoretical consequence that the reaction on the Moon would produce an apparent acceleration of the mean motion. It remained for Professor Darwin to point out that if the Earth were not very nearly rigid, an analogous tidal effect throughout its mass would produce a very much greater outstanding secular acceleration than that actually observed, whether the Earth be assumed viscous or very nearly perfectly elastic. Lastly, in the Memoir numbered (4) it is shown to be probable that, if we trace the Earth-Moon system backwards towards the point of separation, the original lunar orbit will make a considerable angle with the plane of rotation of the primæval planet, unless the Earth's viscosity be very large.

These four independent investigations thus point to the same conclusion—that the Earth must be enormously stiff; and are strongly confirmatory of Sir William Thomson's view that the Earth is solid throughout.

I pass now to the principal investigation of the second Memoir, in which a new light is thrown on the possibilities of planetary evolution. We have seen how, in 1877, Professor Darwin contemplated the separation of the Moon from the Earth at a time when the Earth was so diffuse as to nearly fill the present lunar orbit; and the subsequent history would have represented the contraction of the Earth and Moon to their present dimensions, their centres of gravity remaining at

* See also *B.A. Report*, 1883.

† *Phil. Trans.*, 1882, pt. i., p. 187. ‡ *Ibid.*, p. 230.

approximately the same mean distance. As I have already remarked, the notion of progressive change in this mean distance, due to the tides raised in one body by the other, was already familiar. It was reserved for our Medallist to show that when the term "*tide*" was extended to include yieldings of the whole mass of either body, the tidal action might be so great as to completely alter the above history. It is shown to be probable that the Moon was detached from the Earth when the latter had contracted to nearly its present dimensions, and that the present magnitude of the lunar orbit is a direct result of tidal interaction. By a very elegant geometrical illustration Professor Darwin has shown in two subsidiary papers* how the history of a system such as that of the Earth and Moon may be traced in its essential features without any reference to actual time. The notion of time is introduced when we assign a law or a numerical value to the viscosity of either planet; but if, without doing this, we recognise that the total energy of such a system must degrade, the chronological order of events becomes apparent, though the lapse of time between successive events is unknown. Initially the two bodies are rotating as a rigid body: the day and the month are the same; the Earth always turns the same face to the Moon and the Moon to the Earth; and they are nearly, if not quite, in juxtaposition. This configuration, however, being one of maximum energy, is essentially unstable, and the two bodies would gradually separate, the rotations of both being retarded, but that of the smaller much more rapidly than that of the larger. Under certain conditions, indeed, the diminution of rotation of the smaller might so far keep pace with its recession that the habit of always turning the same face to it might be sensibly retained throughout; and in the case of our Moon this habit was probably acquired very early in the history of the Earth. But with the parent body it would be different. The tides raised in it by the gradually receding satellite would indeed retard its rotation; but for some time the enlarging of the orbit of the satellite would increase its period of revolution much more rapidly, so that the number of days in a month (adopting the specific terms of our own system) would increase from the initial unity. But not indefinitely. After reaching a maximum, they would again diminish to unity, and we should ultimately reach a stage when the Earth and Moon were rotating as a rigid body, but at a considerable distance from each other. The tidal interaction of the two would be exhausted, and the configuration would be now one of minimum energy, and therefore stable. From this point their history would be concerned with the action of the Sun and other external bodies.

* "The Determination of the Secular Effects of Tidal Friction by a Graphical Method," *Proc. R. S.*, 1879; and "On the Analytical Expressions which gave the History of a Fluid Planet of Small Viscosity attended by a Single Satellite," *Proc. R. S.*, 1880.

In the geometrical construction above referred to Professor Darwin shows how these two limiting configurations are determined by the solution of the biquadratic equation

$$x^4 - hx^3 + 1 = 0,$$

which cannot have more than two real roots. In the simplest case of the problem, when the satellite is taken to be a point revolving in an orbit perpendicular to the axis of rotation of the planet, the equation appears at once; and in the more general case the expression on the left also occurs as the denominator in various integrals involved. The equation was originally obtained by seeking the condition that the Moon should always turn the same face to the Earth; but its fundamental significance is better represented by considering it as the condition that the energy of the system should be a maximum or minimum.

Now, in Memoir No. (2) of the five quoted above, Professor Darwin undertakes to trace the history of the Earth-Moon system backwards from its present configuration towards that of maximum energy on the hypothesis of a viscous Earth, and he obtains the surprising result that the internal tidal friction of such a viscous Earth would be sufficient to explain the present recession of the Moon, supposing it to have been separated from an Earth of nearly the present dimensions. He calculated the law of change of the day, the month, and the Moon's mean distance at the present time, and thus reduced previous concomitant values of the day, the month, and the Moon's mean distance. He finds that the number of days in a month, after increasing slightly for a time, diminishes as we go backwards (for one of the most interesting subsidiary results of the Memoir under consideration is that our Earth and Moon have at the present time passed through that configuration referred to above, when the number of days in a month is a maximum), and at the same time the distance of the Moon decreases. But the important point discovered by Professor Darwin is that when the day is as long as the month the Moon has nearly reached the surface of the Earth as we know it. The following table shows the course of the changes as we look backward from the present time:—

Time in millions of years.	Sidereal day in M.S. hours.	Moon's sidereal period in M.S. days.	No. of days in month.	Moon's distance in Earth's mean radii.
	h	d		
0·00	23·93	27·32	27·40	60·4
46·30	15·50	18·62	28·83	46·8
56·60	9·92	8·17	19·77	27·0
56·80	7·83	3·59	11·01	15·6
56·81	6·75	1·58	5·62	9·0
...	5·60	0·23	1·00	1·5

The whole of these results, excepting those in the last line, are derived from an integration by quadratures, on the hypothesis of a certain degree of viscosity of the Earth's mass. That degree of viscosity was so chosen as to be competent to produce the change of configuration in about the shortest possible times. Thus the time-scale in the first column must be regarded as a scale of inferior limits. It might be supposed from an inspection of this table that the changes took place at an ever-increasing rate as we look more and more remotely into the past, but this is not the case: for we finally come to a time when the changes proceeded slowly. The degree of retardation is, however, undetermined, and thus the length of the day when the month was equal to it can only be deduced from the equation of conservation of angular momentum, and this equation gives us no indication of the elapsed time.

"It is particularly important to notice that all the changes might have taken place in fifty-seven million years; and this is far within the time which physicists admit that the earth and moon may have existed. It is easy to suggest a great many *veræ causæ* for changes in the planetary system, but it is ingeneral correspondingly hard to show that they are competent to produce any marked effects without exorbitant demands on the efficiency of the causes and on lapse of time. It is a question of great interest to geologists to determine whether any part of these changes could have taken place during geological history," and on consideration this does not seem impossible.

Further, seeing that the results obtained point strongly to the conclusion that, if the Moon and Earth were ever molten viscous masses, then they once formed parts of a common mass, we are led to the inquiry as to how and why the planet broke up. "The conditions of stability of rotating masses of fluid are unfortunately unknown, and it is therefore impossible to do more than speculate on the subject. The most obvious explanation is similar to that given in Laplace's nebular hypothesis, namely, that the planet, being partly or wholly fluid, contracted, and thus rotated faster and faster until the ellipticity became so great that the equilibrium was unstable, and then an equatorial ring separated itself, and the ring finally conglomerated into a satellite. This theory, however, presents an important difference from the nebular hypothesis, in as far as that the ring was not left behind 240,000 miles away from the Earth when the planet was a rare gas, but that it was shed only 4,000 or 5,000 miles from the present surface of the Earth when the planet was perhaps partly solid and partly fluid. This view is to some extent confirmed by the ring of *Saturn*, which would thus be a satellite in the course of formation. It appears to me, however, that there is a good deal of difficulty in the acceptance of this view when it is considered along with the numerical results of the previous investigation." The chief difficulty is the smallness of the angular velocity indicated for the Earth at the time of rupture. "It seems

improbable that a rotation in a little over 5^h, with an ellipticity of one-twelfth" (very little in excess of that of *Jupiter*) "would render the system unstable."

Professor Darwin is thus led to a very ingenious suggestion as to the cause of rupture—viz., that the natural period of oscillation of the spheroid might be nearly coincident with that of the solar semi-diurnal tide, which would thus acquire a very large amplitude according to the elementary theory of vibrations. "Sir William Thomson has shown that a fluid spheroid of the same mean density as the Earth would perform a complete gravitational oscillation in $1^h\ 34^m$. The speed of oscillation varies as the square root of the density; hence it follows that a less dense spheroid would oscillate more slowly, and therefore a spheroid of the same mean density as the Earth, but consisting of a dense nucleus and a rarer surface, would probably oscillate in a longer time than $1^h\ 34^m$." *

It seems that tidal action may therefore have been responsible not only for much of the history of the Earth and Moon from their separation till the present time, but even for the separation itself, and it is hardly necessary to point out how great a modification of the Nebular Hypothesis this involves. I must again call your attention to the fact that large assumptions were made at the outset of these calculations. It was assumed that the Earth is homogeneous and viscous, and has a certain degree of viscosity, such that with the present length of day the semi-diurnal tide lags by $17°\ 30'$, which particular value makes the rate of change of obliquity nearly a maximum. Further, it was assumed that this viscosity remained constant as we trace the history of the Earth backward. Part of the calculations were repeated on a supposition of variable viscosity, and no serious modification of the results was found, which is so far satisfactory; and there are several instances in the investigations where the nature of the original hypothesis is found to have unexpectedly little influence on the results. Professor Darwin remarks that "whatever may be thought of the theory of the viscosity of the Earth and of the large speculations to which it has given rise, the fact remains that all the effects which have been attributed to the action of bodily tides would also follow, though probably at a somewhat less rapid rate, from the influence of ocean tides upon a rigid nucleus." This unimportance of the original hypothesis, indeed, almost seems to be characteristic of the whole subject, and no better illustration of it could be given than a conclusion of Sir William Thomson, several times quoted by Professor Darwin,† that the precession of a fluid spheroid would sensibly follow the same laws as though it were rigid. And we have already quoted the fact that the hypothesis of viscosity and nearly perfect elasti-

* *Phil. Trans.*, 1879, pt. ii., p. 537.

† See *Obs.*, vol. i., and Address to Section A, British Association, Glasgow, September 1876. The precession of a fluid spheroid has been ably treated by Mr. Bryan in a paper in the *Phil. Trans.* for 1889.

city of the earth would equally well explain the *amount* of the lunar secular acceleration, though in totally different ways.

In a later Memoir (No. (4) of the above series) Professor Darwin is led to modify his view of the initial state of the Earth-Moon system. In the table given above the effects of solar tidal friction have been practically neglected soon after leaving the present configuration. For as we go backwards the approach of the Moon to the Earth would produce a rapid increase of the lunar tides with reference to the solar. But as we approach the limiting configuration it is obvious that, though the tides raised in each body are large, the mutual tidal friction becomes small and ultimately vanishes when the two bodies rotate as a rigid body. The solar tidal friction can, therefore, not be neglected near this limiting configuration. On examination it is found that the effects of the solar tide would be slight save at the most remote period. On the whole, the effect of tidal friction would be to retard (looking backwards) the coincidence of the month and day, so that they would not reach equality until each was reduced to about 2 or $2\frac{1}{2}$ hours instead of $5^h\ 36^m$, and the surfaces of the two bodies would be nearly in contact, instead of there being even the small separation shown in the last line of the table. "Now it is a remarkable fact that the most rapid rate of revolution of a mass of fluid of the same mean density as the Earth, which is consistent with an ellipsoidal form of equilibrium, is $2^h\ 24^m$. Is this a mere coincidence, or does it not rather point to the break-up of the primæval planet into two masses in consequence of a too rapid rotation?"*

In this Memoir he also develops the general theory of the secular changes in the elements of the orbit of a satellite—that is to say, those elements which contain a description of the nature of the orbit; the mean distance, inclination, and eccentricity. It was remarked early in this Address that Professor Darwin's attention seems to have been originally attracted by the varied obliquities of the planetary axes to the ecliptic, and the whole of his work may be regarded as in a measure directed towards the quantitative explanation of these. In the paper on "Precession" he traced the changes in the obliquity of the Earth's axis sympathetic with those in the day, the month, and the distance of the Moon. But there the Moon's orbit was assumed to be circular and confined to the ecliptic. The introduction of eccentricity and inclination of the lunar orbit is found to modify the results of the former Memoir, and I have accordingly not referred to them. In the more complete discussion of Memoir (4) the changes in the inclinations (neglecting the eccentricity) of the lunar orbit are first followed backwards from the present configuration on two hypotheses—one that the viscosity is small, and the other that it is large. It has already been remarked that on the former supposition, when the day

* *Phil. Trans.*, 1880, pt. ii., p. 835.

and month are identical, we find the lunar orbit inclined at a considerable angle to the ecliptic; and in this case it would be difficult to believe that the Moon is a portion of the primæval planet detached by rapid rotation or by other causes. But by supposing the viscosity large enough, "we can trace the system back until the lunar orbit is sensibly coincident with the equator, and the equator is inclined to the ecliptic at an angle of 11° or 12°."* Next, the inclination of the lunar orbit is neglected for the study of changes in the eccentricity, and as an illustration of the interesting nature of such investigations I may quote one of the results obtained incidentally: †

"In the history of a satellite revolving about a planet of small viscosity, the circular orbit is dynamically unstable until 11 months of the satellite have become longer than 18 days of the planet. Since the day and month start from equality and end in equality, it follows that the eccentricity will rise to a maximum and ultimately diminish again."

Combining the two investigations, Professor Darwin shows how the history of the Earth-Moon system may be sketched from our present knowledge and the supposition that they originally formed part of the same planet.

"We begin with a planet not very much more than 8,000 miles in diameter, and probably partly solid, partly fluid, and partly gaseous. This planet is rotating in a period of from 2 to 4 hours about an axis inclined at about 11° or 12° to the normal to the ecliptic" (or even less if we include the effects of solar tidal friction; so that there is nothing extravagant in the supposition that it originally formed part of the Sun), "and is revolving about the Sun with a period not very much shorter than our present year." ‡ The planet separates into two masses, owing to rotational instability or tidal action, the larger being the Earth, and the smaller the Moon: they are nearly in contact with one another, and rotating nearly as though they were parts of one rigid body. The attraction of each distorts the other, and the Sun raises tides in both. In consequence of frictional resistance such a system is dynamically unstable. The Moon probably revolved a little slower than the Earth rotates—*i.e.*, the month was a little longer than the day—and this excess would tend to increase. Also "the axial rotation of the Moon is retarded by the attraction of the Earth on the tides raised in the Moon, and this retardation takes place at a far greater rate than the similar retardation of the Earth's rotation. As soon as the Moon rotates round her axis with twice the angular velocity with which she revolves in her orbit, the position of her axis of rotation (parallel with the Earth's axis) becomes dynamically unstable. The obliquity of the lunar equator to the plane of the orbit increases, attains a maximum, and then

* *Phil. Trans.*, 1880, pt. ii., p. 874.

† *Ibid.*, p. 877.

‡ *Ibid.*, p. 879.

diminishes. Meanwhile the lunar axial rotation is being reduced towards identity with the orbital motion.

"Finally her equator is nearly coincident with the plane of her orbit, and the attraction of the Earth on a tide which degenerates into a permanent ellipticity of the lunar equator causes her always to show the same face to the Earth."

As the month increased the lunar orbit became eccentric, and the eccentricity (never probably large) would reach a maximum and then continually decrease if the viscosity had remained unchanged; but as the Earth became more rigid and oceans with tides were formed, the decrease of eccentricity would gradually cease, and then again increase.

The plane of the lunar orbit is at first identical with that of the equator; but as the Moon recedes from the Earth the Sun's action is felt. Consequently the inclinations of the lunar orbit and equator to their proper planes increase to maximum values, and then decrease. Meanwhile these reference planes, which originally nearly coincided with the equator, open out, the inclination of the lunar proper plane to the ecliptic diminishing, while that of the terrestrial equator increases; and gradually the system arrives at its present state after an estimated period of fifty-four million years.

Professor Darwin thinks it hardly too much to say that if only sufficient time be granted for the process, and it be admitted that the diffused matter in the universe produces no material change in the motions of the Earth and Moon during the period of evolution, then some such system as ours must have been developed from a primæval planet, though the process might vary in detail. He says finally:—

"A theory, reposing on *veræ causæ*, which brings into quantitative correlation the lengths of the present day and month, the obliquity of the ecliptic, and the inclination and eccentricity of the lunar orbit, must, I think, have strong claims to acceptance."

Before passing from the study of the particular system which has most interest for us, and which, as we shall presently see, there is reason for believing to be unique in the solar system—that of the Earth and Moon—to the other planetary systems, attention may be briefly directed to the results of the third Memoir of the series, to which reference has not yet been made. In this several problems are discussed which suggest themselves in the course of the main investigation, but do not affect the main argument. The first of these is the distortion of the spheroid when it is subjected to tidal stress throughout its mass. "There is an unequal distribution of the tidal frictional couple in various latitudes. We may see in a general way that the tidal protuberance is principally equatorial, and that accordingly the Moon tends to retard the diurnal rotation of the equatorial portions of the sphere more rapidly than that of the polar regions. Hence the polar regions tend to outstrip the equator, and there is a

slow motion from west to east relatively to the equator." * But a numerical examination shows that no sensible effect of this kind can have occurred within recent geological times, although it may have been once sensible. It has had little or nothing to do with the observed crumpling of strata, but it may afford a possible explanation of the north and south trend of our great continents.

The second problem considered is that of the generation of heat by tidal friction. The kinetic energy lost by degradation must reappear as heat, which would have to be added to that due to the slow contraction of the Earth in any investigation as to its secular cooling. Numerical calculation, however, shows that the heat generated would be fairly represented by a temperature gradient from the surface downwards of about 1° Fahrenheit in 2,600 feet, whereas the observed temperature gradient, though very variable, is far greater: so that the effects of tidal friction are completely masked by those of contraction, and "Sir W. Thomson's investigation of the secular cooling of the Earth is not sensibly affected by these considerations." †

The third problem treats of the effects of inertia on the tides of a viscous spheroid, which have previously been shown to be unimportant for the purposes of the present inquiry.

In the fifth Memoir Professor Darwin passes from the Earth-Moon system to the other planets in detail. He has already made brief references to them in the fourth Memoir, pointing out how the small planet *Mars* fulfils our expectations that it should be far advanced in its evolution by presenting the only case in the whole system where a satellite is moving faster than the primary rotates, which will be the ultimate fate of our Moon; for "after the Moon's orbital motion has been reduced to identity with that of the Earth's rotation, solar tidal friction will further reduce the Earth's angular velocity, the tidal reaction on the Moon will be reversed and the Moon's orbital velocity will increase, and her distance from the Earth will diminish. But since the Moon's mass is very large, the Moon must recede to an enormous distance from the Earth before this reversal will take place. Now the satellites of Mars are very small, and therefore they need only to recede a short distance from the planet before the reversal of tidal reaction." ‡

When, however, the effects of tidal friction on the evolution of other planetary systems are considered numerically, Professor Darwin finds the startling result that the case of the Earth and Moon is probably unique. The separation of other satellites from their primaries, and of the planets themselves from the Sun, probably occurred in the manner suggested in the Nebular Hypothesis, and which was always assumed to be applicable to the Earth and Moon before the effects of tidal friction were investigated—

* *Phil. Trans.*, 1879, pt. ii., p. 588. † *Ibid.*, p. 593.
‡ *Phil. Trans.*, 1880, pt. ii., p. 883.

that is to say, the present orbits of the satellites roughly indicate the sizes of the parent bodies at the time of separation. Retrospectively, it is comparatively easy to recognise the singular character of our own system. It is a link between the planets which (as far as we know at present) are unattended and those which have satellites; and we have seen reason for believing that the separation of the Moon from the Earth was possibly more or less of an accident, and due to extraneous causes, such as the near coincidence of two harmonic periods. The abnormal character of our satellite is also indicated by its large size in comparison with the parent body; and when we proceed to the comparison of the orbital momentum of the satellites with the rotational momentum of the parent body, we find a ratio of 4·78 for our own system, while it seems improbable that this ratio can exceed ·04 for *Saturn*, the most favourable case among the other planets. On using such approximate numerical data as are available, Professor Darwin concludes that it appears unlikely that the satellites of "*Mars*, *Jupiter*, and *Saturn* originated very much nearer the present surfaces of the planets than we now observe them. But the data being insufficient, we cannot feel sure that the alteration of the dimensions of the orbits of these satellites has not been considerable. It remains, however, nearly certain that they cannot have first originated almost in contact with the present surfaces of the planets, in the same way as, in previous papers, has been shown to be probable with regard to the Moon and the Earth."

Further, the progressive decrease in the number of satellites as we pass from the outer planets to the inner may be connected with the increasing efficiency of solar tidal friction as we approach the Sun. The detaching of a satellite from a contracting planetary mass is probably a result of the increase of rotational velocity due to contraction. Now, solar tidal friction tends to check the rotation of the planet. For the outer planets the solar tidal friction would be small, and not sufficient to seriously retard the increase of rotation due to contraction, so that one or more satellites would be shed at successive epochs of instability. But for the nearer planets the influence of solar tidal friction would be greater; and for the Earth there may have been "for a long time nearly a balance between the retardation due to solar tidal friction and the acceleration due to contraction, and it was not until the planetary mass had contracted to nearly its present dimensions that an epoch of instability could occur." For the planets within the Earth, *Mercury* and *Venus*, not only are the effects of solar tidal friction manifested by the absence of satellites, but we have more recent evidence in the observations of M. Schiaparelli that its work is now complete. If M. Schiaparelli's conclusions are correct, the great solar tides have reduced these planets to the condition of our own Moon, rotating in the period of revolution round the primary.

In giving this brief sketch of the main outlines of Professor Darwin's work much has been omitted, for obvious reasons, that is of interest and importance. If some of the conclusions should appear speculative, it must be borne in mind that the main argument is the unexpected result of a mathematical investigation, and not an original speculation supported by subsequent analysis. For this reason the ideas recorded by Professor Darwin in 1877 have been contrasted with the results of his principal Memoir on the history of the Earth and Moon. There is no doubt that he has been at times hampered by the lack of sufficient data, and at others has not been able to represent known facts in our limited mathematical analysis; but if these are drawbacks from the point of view of great accuracy in the conclusions, from another standpoint they are advantages as indicating the deficiencies which it is important to supply in the future. Professor Darwin has shown how there may be correlations between the viscosity of the Earth, the change of obliquity of the ecliptic, and the Moon's secular variation; between the configuration of planetary systems and the rigidity of the matter composing them. And he has thus indicated how, in the future, one department of astronomy may benefit by increase of knowledge in another; and he has added a new link between astronomy and physics, which may in the future mean new opportunities for both. Let us hope that the time for taking advantage of them may not be delayed by any fault of astronomers!

Let us now turn for a few moments to the more practical work of our Medallist, which is also specified in the award. He has proved himself on several occasions skilful in experiments more or less related to his theoretical investigations. The reports which (in conjunction with his brother, Mr. Horace Darwin) he has made to the British Association on the lunar disturbance of gravity record a series of ingenious and very delicate experiments, which, unfortunately, disturbing causes rendered useless. And, although the subjects of our Medallist's theoretical work are generally beyond the reach of laboratory experiments, yet in such papers as that "On the Formation of a Ripple-mark in Sand" (a passing glance at the diagrams in which will show how ingeniously and prettily the complex nature of the liquid vortices is made manifest) and "On the Horizontal Thrust of a Mass of Sand" (whose value was acknowledged by the award of a medal by the Institute of Civil Engineers), we recognise a relationship to the study of the wrinkling of the Earth's surface into continents, and the stresses caused in its interior by their weight.

But Professor Darwin has done practical work of a most useful kind in another sense. It has in recent years fallen to his lot to undertake most of the laborious work necessary for the practical study of the ocean tides. Fifty years ago, though the general phenomena were known and some examination made of tides in various parts of the world, yet it was mainly in European seas

that extensive series of observations were available or that any attempt had been made to deal with them adequately; but the methods were imperfect, and the reductions required the constant exercise of much skill. The great advance of our modern knowledge is mainly due to the energy of the British Association and its committees. Two Reports, in 1872 and 1876, chiefly due to Sir W. Thomson, may be considered the first important step towards an extensive study by harmonic analysis. All the phenomena now, instead of being referred to the Sun's and Moon's hour angles, declinations, and parallaxes, were considered as harmonic functions of angles varying uniformly with the time; the entire phenomenon was looked on as the sum of a number of harmonic undulations depending directly on the Sun's and Moon's mean hour angles and longitude, &c., which increase directly as the time. This great simplification has enabled work to be undertaken which would previously have been impossible.

In the Report for 1883 Professor Darwin devoted himself to the revision and development of the method of these two reports and the production of a manual for harmonic analysis. "A committee," he remarks, "appointed for the examination of the question of the harmonic analysis of tidal observations practically finds itself engaged in the reduction of Indian tidal observations, since it is only in that country that any extensive system of observation, with systematic publication of results, exists." The Indian work was till comparatively recently carried out by Major (now Lieut.-Colonel) Baird, R.E., and has consisted in the observation and discussion of the tides at a number of places on the Indian coasts for which tide tables are now annually published by the Indian Government.

Since then something has been done elsewhere; but if we consider the great amount which might be done, the result is lamentably small. Forms for reduction have been printed, with full directions, but apparently the cost of reduction is still so great as to deter most Governments from undertaking the work on any large scale; and it may be admitted that in many cases the scientific interest is of greater importance than the practical value of discussing very large series of observations.

Recognising the importance of this consideration, Professor Darwin has recently turned his attention to supplying such data as will suffice for sailors, to whom it is of importance to know the times and heights of high and low water at certain points near the entrances to ports. Unfortunately, excepting in the North Atlantic, where the diurnal tides are very small, such information is very scanty and inaccurate. "When there is a large diurnal inequality, as is commonly the case in other seas, the heights and intervals, after the upper and lower lunar transits, are widely different; the two halves of each lunation differ much in their characters, and the season of the year has great influence. . . . The tidal information supplied by the Admiralty for such places consists of rough means of the rise

and interval at springs and neaps, modified by the important warning that the tide is affected by diurnal inequality." Such information being almost useless, Professor Darwin devised an approximate but very cheap and simple method (described in the Bakerian Lecture at the Royal Society about a year ago) for predicting tides at any port after a very moderate amount of computation. He is, it is believed, at present occupied with the further simplification of this method by some mechanical contrivances, and we may sincerely hope that his efforts may be successful and lead to a great practical improvement in tide tables everywhere.

If it were generally known that for any port whose tidal constants are known the curves could be furnished for a very small cost, I cannot but think that many ports where tidal observations have been made would go to the expense of having them discussed, and that tide gauges would be established to make observations.

The President, then delivering the Medal to Professor Darwin, addressed him in the following terms:—

Professor Darwin, I have now to complete my duty here by delivering to you the medal which the Council have awarded. As your father taught us how the action of admitted laws would allow us to trace back all living nature to the first slight germs of life and thus account for the wonderful and beautiful diversity around us, so you, in your turn, have endeavoured to trace back the fabric of the world and solar system to its remote origin. Neither your subject nor the mode of investigation you have necessarily followed will admit of your work meeting with that general assent which almost at once greeted your father's, but we hope that this medal may serve to assure you that its value is appreciated, and encourage you to perfect the outlines and fill up the details of the sketch you have given to us. That you may have health and strength to continue your labours is the best we can wish you.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

E. B. Knobel, Esq.

Vice-Presidents.

W. H. M. Christie, Esq., M.A., F.R.S., Astronomer Royal.
J. W. L. Glaisher, Esq., M.A., Sc.D., F.R.S.
E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.
Lieut.-Gen. J. F. Tennant, C.I.E., R.E., F.R.S.

Treasurer.

A. A. Common, Esq., LL.D., F.R.S.

Secretaries.

E. W. Maunder, Esq.
H. H. Turner, Esq., M.A., B.Sc.

Foreign Secretary.

William Huggins, Esq., LL.D., D.C.L., F.R.S.

Council.

Captain W. de W. Abney, C.B., R.E., D.C.L., F.R.S.
Arthur Cayley, Esq., M.A., Sc.D., LL.D., D.C.L., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge.
Hon. Sir James Cockle, M.A., F.R.S.
A. M. W. Downing, Esq., M.A., Superintendent of the "Nautical Almanac."
George Knott, Esq., B.A., LL.B.
Frank McClean, Esq., M.A.
W. H. Maw, Esq.
W. E. Plummer, Esq., M.A.
A. Cowper Ranyard, Esq., M.A.
Isaac Roberts, Esq., F.R.S.
Rev. Walter Sidgreaves, S.J.
E. J. Spitta, Esq.

MONTHLY NOTICES

OF THE

Fellows of the Society are informed that at the last meeting of the Council it was decided:—

That papers for the *Memoirs* be published separately, and distributed immediately to such of the Fellows as desire to have them as published instead of the volume of *Memoirs*, and that these separate copies be also on sale.

This arrangement will commence with Volume LI.

"Wellesley" Training Ship (proposed by David Gill);
Humphrey Barker Chamberlin, 1033 Sixteenth Street, Denver, Colorado, U.S.A. (proposed by H. H. Turner);
Otto Jaffe, German Consul, Kin Edar, Strandtown, Belfast, Ireland (proposed by J. L. E. Dreyer);
Charles Henry Johns, M.A., Althorpe House, Waverley Grove, Hendon, Middlesex (proposed by J. D. McClure);
William Grant MacGregor, 18 Coleman Street, E.C. (proposed by R. Grant);
Captain R. Reynolds, Lieutenant, R.N.R., U.S.S. "Pretoria," Southampton (proposed by D. Forbes);
Albert Edward Watson, B.A., F.R.Met.Soc., Whitgift Grammar School, Croydon (proposed by Charles B. Neate).

One hundred and twelve presents were announced as having been received since the last ordinary meeting; including, amongst others :—

The Milky Way, drawn at the Earl of Rosse's Observatory, Birr Castle, by Otto Bœddicker, presented by the Earl of Rosse; Comparative Photographic Spectra of the Sun and Metals, and Comparative Photographic Spectra of the High Sun and Low Sun, presented by F. McClean; Photographs of the Spectroscope at the Kenwood Physical Observatory, Chicago, presented by G. E. Hale; Telegraphic Longitudes in Western Australia, presented by the Hydrographer; Recherches sur la Rotation du Soleil, presented by N. C. Dunér; O. Bœddicker, Lunar Radiant Heat, measured at Birr Castle Observatory, presented by the Earl of Rosse.

On the Dynamics of the Earth's Rotation, with respect to the Periodic Variations of Latitude. By Simon Newcomb.

The recent remarkable discovery of Mr. S. C. Chandler, that the axis of rotation of the Earth revolves around the axis of maximum moment of inertia in a period of about 427 days, is worthy of special attention.* At first sight it seems in complete contradiction to the principles of dynamics, which show that the ratio of the time of such a rotation to that of the Earth's revolution should be equal to the ratio of the polar moment of inertia of the Earth to the difference between the equatorial and the polar moments. Representing these moments by A and C, it is well known that the theory of rotation of a rigid body gives the equation

$$\tau = \frac{A}{C-A},$$

τ being the period of rotation of the pole in sidereal days.

Now the ratio in question is given with an error not exceeding a few hundredths of its total amount by the magnitude of the precession and nutation. The value found by Oppolzer is $\frac{1}{305}$, giving the time of rotation as 305 days.

This result has long been known, and several attempts have been made to determine the distance between the two axes, especially at Poulkova and Washington. A series of observations was made with the Washington Prime Vertical Transit during the years 1862–1867, including six complete periods of the inequality. Thus the determination of the coefficient and zero of the argument is completely independent of all sources of error having an annual or diurnal period. Such errors are

* *Astronomical Journal*, Numbers 248, 249.

liable to affect the determination unless it is continued over this period.

A preliminary discussion of the observations, which was made at the request of Sir William Thomson, and published by him, gave a coefficient of $0''.05$ for the inequality. A more complete discussion, undertaken quite recently, reduces the coefficient to $0''.03$, corresponding to a distance of three feet between the two axes. This result was quite within the limits of errors of observation, and seemed to show that there was no appreciable difference between the two axes. This result was in complete accordance with the conclusions reached from the Poulkova observations, and seemed to show, beyond doubt, that there could be no inequality of the kind looked for.

Mr. Chandler's discovery gives rise to the question whether there can be any defect in the theory which assigns 306 days as the time of rotation. The object of this paper is to point out that there is such a defect—namely, the failure to take account of the elasticity of the Earth itself, and of the mobility of the ocean.

The mathematical theory of the rotation of a solid body, on which the conclusions hitherto received have been based, presupposes that the body is absolutely rigid. As the Earth and ocean combined are not absolutely rigid, we have to inquire whether their flexibility appreciably affects the conclusions. That it does can be shown very simply from the following consideration:—

Imagine the Earth to be a homogeneous spheroid, entirely covered by an ocean of the same density with itself. It is then evident that, if the whole mass be set in uniform rotation around any axis whatever, the ocean will assume the form of an oblate ellipsoid of revolution, whose smaller axis coincides with that of rotation. Hence, the axes of rotation and of figure will be in perfect coincidence under all circumstances.

To apply a similar reasoning to the case of the Earth, imagine that the axis of rotation is displaced by $0''.20$ from that of greatest moment of inertia, which I shall call the axis of figure. Then, with an ocean of the same density as the Earth, its equator would be displaced by the same amount. The ocean level would change in middle latitudes by about one inch at the maximum. But this change would have for its effect a corresponding change in the axis of figure. As the ocean covers only three-fourths of the Earth, the axis would be displaced by three-fourths of the distance between the two axes, were ocean and Earth of equal density. But, as the density of the Earth is some five times as great, the actual change would be only one-fifth of this. It would even be less than one-fifth, because the displacement of the ocean equator would be resisted by the attraction of the Earth itself. The exact amount of this resistance cannot be accurately given, but I think the displacement would thereby be

reduced to one-half. I therefore think that one-fourteenth would be an approximate estimate of the displacement of the axis of figure, in consequence of the movement of the ocean. As Mr. Chandler's period requires a displacement of two-sevenths, the ocean displacement only accounts for one-fourth of the difference.

The remainder is to be attributed to the elasticity of the Earth itself. It is evident that the flexure caused by the non-coincidence of the two axes tends to distort the Earth into a spheroid of the same form as that which the ocean assumes, and thus to bring the two axes together.

We have now to show how this deformation of the Earth changes the time of revolution. Let us imagine ourselves to be looking down upon the North Pole, and let P be the actual mean pole of the Earth when the two axes are in coincidence, and R the end of the axis of rotation. Then, in consequence of the rotation around R, the actual pole will be displaced to a certain point, P′. Now, the law of rotation of R is such that it constantly moves around the instantaneous position of P′ in a period of 305 days, irrespective of the instantaneous motion of P′ itself. In other words, the angular motion of R at each moment is that which it would have if P′ had remained at rest. Hence, the angular motion as seen from P is less than that from P′, in the ratio of P′ R : P R.

But, as R rotates, P′ continually changes its position and rotates also, remaining on the straight line PR. Thus the time of revolution of R around P is increased in the same ratio.

We may next inquire what degree of rigidity the Earth must have in order that the total displacement of the axis of figure produced by the change in the centrifugal force may be two-sevenths that of the displacement of the axis of rotation; in other words, that the ratio P′R : PR may be 5 : 7. A rigorous treatment of the problem is scarcely possible, as the rigidity probably varies from the surface inward; I shall therefore only attempt a rough estimate, founded on certain conclusions as to the deformation of a rotating spheroid reached in Thomson and Tait's *Natural Philosophy*. To proceed in the simplest way, I shall assume the earth to have the rigidity of steel, and inquire to what displacement the axis of figure would be subject, in consequence of the centrifugal force arising from a rotation around an axis differing from the normal axis of figure.

Conceive a solid sphere, of the same size and general constitution as the Earth, to be set in rotation like the Earth. Let ϵ' be the ellipticity induced in it by the rotation, and let ϵ be the actual ellipticity of the Earth. We shall then have a superposition of two ellipticities, the one ϵ, such that P is the pole of figure; the other, ϵ' such that R is the pole of figure. P′ being the pole arising from the combined ellipticities, I assume that we have the proportion

$$PP' : \epsilon' = P'R : \epsilon.$$

To find the value of ϵ' I start from the conclusion of Thomson

and Tait (§837), that a ball of steel of any radius rotating with an equatorial velocity of 10,000 centimètres per second will be flattened to an ellipticity of $\frac{1}{7220}$. The Earth's equatorial velocity is 4·65 times this. Its density is less than that of steel: the density which we should assume is not the actual mean density but a mean in which greater weight is given to the superficial portions, because these have the greatest centrifugal force. Probably the actual mean to be adopted is 0·6 of the density of steel. We have, therefore, neglecting the effect of gravitation,

$$\epsilon'_0 = \frac{0 \cdot 6 \times 4 \cdot 65^2}{7220} = \frac{1}{557}.$$

But the deformation of the Earth is resisted by the gravitation of its parts. By a theorem given by Thomson and Tait, we should have, taking this effect into account—

$$\frac{1}{\epsilon'} = \frac{1}{\epsilon'_0} + \frac{1}{\epsilon} = 557 + 292 = 849.$$

Hence we have

$$\epsilon' = \frac{1}{849}.$$

Hence, considering only the solid Earth,

$$PP' : P'R = 292 : 849.$$

We have already concluded that the motion of the ocean will shift P′ one-fourteenth of the way from P′ to R. Hence, finally,

$$PP' : P'R = 353 : 788$$
$$PR : P'R = 1142 : 788.$$

Time of revolution of pole	= 443 days
Period for a rigid earth	= 306 ,,
Computed increase of period	= 137 ,,
Observed increase of period	= 121 ,,

The conclusion is that the Earth yields slightly less to the centrifugal force than it would if it had the rigidity of steel, and that it is consequently slightly more rigid than steel.

We have next to consider the effect of viscosity of the earth. Those geologists who have given special attention to the subject regard it as well established that the Earth yields under the weight of deposits as if it were a thin crust floating upon a liquid interior, and must therefore be a viscous solid, if a solid at all. The effect of viscosity is that the normal pole P of the Earth would be in slow but continuous motion towards the revolving pole R. Both P and R would then describe logarithmic spirals, so related that the tangent to the inner spiral at the position of P at any moment would pass through the position of R at that moment, and cut the R spiral normally. Thus the line PR would diminish from century to century by equal

fractions of its amount in equal times. Thus the poles would eventually appear to meet, unless separated from time to time by the action of causes changing one or both of them.

Since the position of the pole of figure of the Earth may be supposed to have been originally determined by the rotation itself, and continually to approach the pole of rotation if it were very slightly separated from it, the presumption would appear to be that the two poles would now be in apparent coincidence, in the absence of disturbing causes. Moreover, the evidence of the most accurate observations hitherto made with Prime Vertical Transits seems to show that the separation of the two poles at the epochs 1842 and 1864 could scarcely have exceeded the tenth of a second. But observations made with probably equal exactness at the present time seem to show, according to Mr. Chandler, a separation of $0''\cdot3$. It would seem, therefore, accepting these provisional numerical results, that some disturbing cause has acted. A *vera causa* was pointed out some years ago by Sir William Thomson, in the motions of the winds and oceans, and especially in changes in the polar ice-cap. In order to have its greatest effect such a movement of matter must occur in the middle latitudes; a change in the polar ice-cap would be the less appreciable in its effect the nearer it occurred to the pole. A heavy snow-fall over the whole of Northern Asia, unaccompanied by a corresponding fall on the American continent, would undoubtedly cause a slight displacement; but I doubt whether the greatest effect of this kind could amount to $0''\cdot05$.

But we have also to consider the effect of an annually repeated disturbance of this kind. Mr. Chandler's period is such that the pole of rotation makes six revolutions in seven years. Hence, during one-half the period of seven years, the effect of an annually repeated cause will be cumulative. In a recent volume of the *Bulletin Astronomique*, Mr. Radau has investigated the effect of an annual periodic change in the position of the Earth's axis of figure, and shown that it will be multiplied three times, in consequence of this cumulative effect. But his analysis rests on the hypothesis of a 306-day period. It is worth while to show how such an annual cause would act when we adopt Mr. Chandler's period.

Let Q be the mean position of the pole of figure of the Earth, and let us assume that the actual pole P revolves around it in a radius a, and in a period of one year. Let R be the position of the pole of rotation at any time. Then, at each moment, R is revolving around the fixed position P with a uniform motion, which, if continued, would cause it to complete a revolution in 427 days. Let us put

n, the mean motion of the radius PQ;

μ, the mean motion of R around the position of P;

x, y, the rectangular co-ordinates of R referred to Q as an origin.

The law of rotation then gives the equations

$$\frac{dx}{dt} = -\mu y + a\mu \sin(nt+c)$$

$$\frac{dy}{dt} = \mu x - a\mu \cos(nt+c).$$

The integration of these equations gives

$$x = \alpha \cos \mu t - \beta \sin \mu t - \frac{a\mu}{n-\mu} \cos(nt+c)$$

$$y = \alpha \sin \mu t + \beta \cos \mu t - \frac{a\mu}{n-\mu} \sin(nt+c),$$

α and β being arbitrary constants.

Substituting for μ and n their numerical values, we have, approximately,

$$x = \alpha \cos \mu t - \beta \sin \mu t + 6a \cos(nt+c)$$

$$y = \alpha \sin \mu t + \beta \cos \mu t + 6a \sin(nt+c).$$

Such a rotation as we have supposed, around a circle of $0''.05$ in radius, would suffice to produce anomalies as large as those actually observed.

If the winters in Siberia and in North America occurred at opposite seasons, we should have no difficulty in accepting the sufficiency of annual falls of snow to account for the anomaly. But, under the actual circumstances, we must await the results of further investigations into the whole subject.

On the Displacement of the Apparent Radiant Points of Meteor-Showers due to the Attraction, Rotation, and Orbital Motion of the Earth. By Joseph Kleiber.

The question of the shifting or immobility of radiant points of meteoric showers has been lately discussed with warmth from the point of view of several observers, in the pages of these *Notices* and elsewhere. As no theoretical investigation into this subject has yet appeared, I trust that the following lines

may be of some interest, and may help to elucidate this question which has been the subject of so much controversy.

There are three principal causes of the displacement of the apparent radiant of a meteor shower. These are—

1. The *attraction* of the Earth.
2. The *rotation* of the Earth.
3. The *orbital motion* of the Earth.

I shall consider these causes separately in the order here indicated, and trace the theoretical curves described by a radiant under the separate influence of each of them, and of the three conjointly, and shall illustrate the theory by applying it to two characteristic examples.

i. The *Perseid swarm*, which is the one chiefly concerned in the discussion alluded to above, and which will furnish an especially good illustration of the *third* of the causes just mentioned;

ii. The *Andromedid swarm*, whose position is especially adapted for illustrating the displacement of a radiant due to the *first* of these causes, and to show how a diffused radiation may be the consequence of the action of this first cause alone.

I. *The Attraction of the Earth.*

The displacement of a meteoric radiant due to the attraction of our planet on every meteor of the shower consists in the fact that the meteors of a swarm describe hyperbolas about the Earth's centre as a focus, instead of describing straight lines, and that the apparent direction of a meteor's path is determined by the direction of the tangent to this hyperbola at the point where it meets the Earth's atmosphere, instead of being determined by the direction of its asymptote—the latter representing the undisturbed path of the meteor. The amount of this displacement, *i.e.* the angle between the tangent to the meteor's visible track and the asymptote, or the direction of its undisturbed motions depends—

(i.) On the relative velocity of the meteors with respect to the Earth; and

(ii.) On the angle between the direction of the path of the meteors, and their radius vector from the Earth's centre, *i.e.* the zenith distance of their radiant.

Formulæ for the computation of the value of this displacement were given more than twenty years ago by G. V. Schiaparelli in his classic work on shooting stars, and they need not be repeated here. Only the final result will be given and applied to numerical examples.

The attraction of the earth *diminishes the zenith distance* of every radiant, leaving its azimuth unchanged.

Let w be the undisturbed relative velocity of the meteors of a particular shower, and w_1 their relative velocity accelerated by the attraction of the Earth. Then the equation of *vis viva* gives

$$w_1^2 = w^2 + 2gr.$$

Let Δz be the difference between the disturbed and undisturbed zenith distance of the radiant, and

Δz_0 the value of Δz when $z = 90°$,

i.e. when the radiant is on the horizon; then Schiaparelli finds—

$$\tan \tfrac{1}{2}\Delta z_0 = \frac{w_1 - w}{w_1 + w},$$

and also

$$\tan \tfrac{1}{2}\Delta z = \tan \tfrac{1}{2}\Delta z_0 \tan \tfrac{1}{2}z.$$

These are the formulæ we shall use in our *second* example. In the particular cases when Δz_0 is small, the following approximate formulæ are more convenient:—

$$\Delta z = c \tan \tfrac{1}{2}z$$

$$c = \frac{a}{w^2} \qquad (\log a = 2{\cdot}941).$$

The usual astronomical units being used, the formulæ give c and Δz in degrees, and Δz having been computed, $\Delta\alpha$ and $\Delta\delta$ may be found from known formulæ.

Example 1. *Perseids.*—Among the many different positions given for the radiant of this swarm, it is difficult to make a choice which will not be to a great extent arbitrary. Again, as all these radiants are deduced from observations uncorrected for any of the three causes here considered, it would be inconsistent to start from values which will be shown to differ sensibly from those that would have been found if appropriate methods were used in the determination of radiants. I prefer, therefore, to take the radiant of the comet 1862 iii. in its node, and to apply to it the corrections here indicated.

The orbit of the comet does not geometrically intersect that of the Earth; but we may dispose of the value of its period of revolution or major axis, so as to give it a real point of intersection. Thus, if we take the following elements of this comet:—

$$\pi = 289°{\cdot}78$$
$$☊ = 137{\cdot}45$$
$$i = 113{\cdot}57$$
$$\phi = 74{\cdot}01,$$

we shall find for the co-ordinates of the radiant point

$$\alpha = 43^\circ{\cdot}58$$
$$\delta = 57{\cdot}08.$$

These values correspond to the epoch when $\odot = 137^\circ{\cdot}45 (= \Omega)$, *i.e.* approximately to August 9·5 (Greenwich time). The periodic time of the comet, or rather of the meteoric swarm moving in the comet's orbit, is found to be 122·9 years, when the orbit of this swarm and that of the Earth really intersect in the node of the former.

From this position of the undisturbed apparent radiant I find that the *elongation of the radiant from the Earth's apex, i.e.* the angle between the direction of the motion of the Earth and the direction of the apparent radiant, is

$$\epsilon = 39^\circ{\cdot}90,$$

and hence *the relative velocity* of the comet in its node is found to be 2·02 times that of the Earth at the same moment, or, in usual astronomical units,

$$\log w = 8{\cdot}5354,$$

and the abridged formulæ of this section give

$$c = 1^\circ{\cdot}03.$$

This is the largest displacement which could be produced on the radiant of the *Perseids* by the attraction of the Earth, if the radiant ever reached the horizon; but this radiant never sets at Greenwich (for which place we are computing all our results), and thus the so-called *zenith-attraction* never attains this value.

In order to give a clear idea of the influence of this disturbing cause on the positions of the radiant at different hours of the night, I have computed the corrections $\Delta\alpha$, $\Delta\delta$, to be applied to its co-ordinates for every three hours, beginning at the moment when the hour angle is 0, and ending twenty-four hours later.

The formulæ for the computation of these corrections are

$$\Delta\alpha \cos\delta = -\Delta z \sin Q$$
$$\Delta\delta = -\Delta z \cos Q,$$

Q being the "parallactic angle."

By means of these formulæ and the figures given above, I find the following corrections :—

TABLE I.

t	ι	Q	$\Delta\iota$	$\Delta\alpha$	$\Delta\delta$	T
h	°	°	°	°	°	h
0	5·6	180·0	−0·05	0·00	−0·05	6
3	26·4	82·7	−0·24	+0·44	+0·03	9
6	48·9	55·7	−0·47	+0·71	+0·26	12
9	65·3	29·0	−0·66	+0·59	+0·58	15
12	71·4	0·0	−0·74	0·00	+0·74	18
15	65·3	331·0	−0·66	−0·59	+0·58	21
18	48·9	304·3	−0·47	−0·71	+0·26	0
21	26·4	277·3	−0·24	−0·44	+0·03	3
	5·6	180·0	−0·05	0·00	−0·05	6

The last column gives the approximate mean time corresponding to the values indicated in the table.

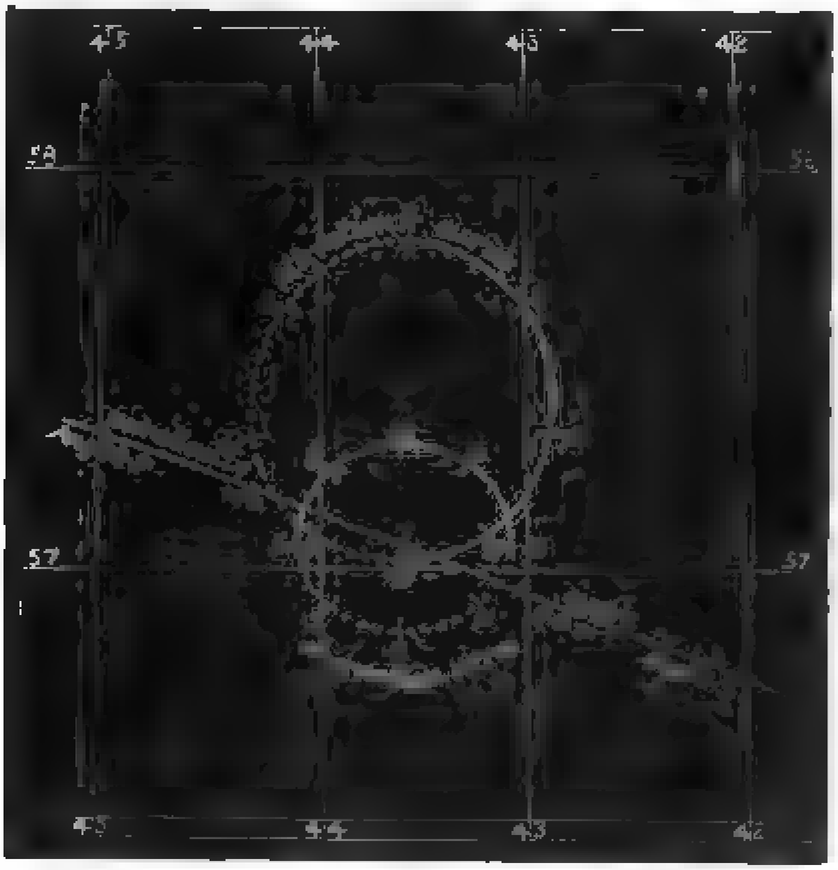


Fig. 1.

Fig. 1 illustrates this table. The attraction curve is an oval described by the radiant in twenty-four hours. The figures along the curve denote the mean Greenwich time of the corresponding position as given in the last column of the table above. We see from the diagram that the undisturbed position of the radiant differs not only from its real position (so far as it is affected by the attraction of the Earth alone) at any particular moment, but also from the mean position of the disturbed radiant during a whole period, the radiant lying very eccentrically in the oval described by its successive disturbed positions.

Example 2. Andromedids.—Very differentis the case of the *Andromedid* swarm. The meteors of the *Perseid* shower possess a large relative velocity, and the disturbing action of the Earth's attraction on the position of its radiant is accordingly comparatively small. The relative velocity of the *Andromedids* is, on the contrary, of the very smallest, and the disturbing action due to the Earth's attraction on them is consequently enormous.

I take here again, as in the former case, the cometary radiant to start from. The elements of the comet Biela being

$$\pi = 108^\circ 97$$
$$\Omega = 245{\cdot}97$$
$$\iota = 12{\cdot}57$$
$$\phi = 49{\cdot}03.$$

I find for the position of the radiant in the node of the cometary orbit the co-ordinates

$$\alpha = 23^\circ{\cdot}27$$
$$\delta = 43{\cdot}12.$$

The epoch of the swarm is approximately November 27·5 (corresponding to $\odot = 245^\circ{\cdot}97$), and the periodic time of the meteoric swarm is found to be 6·72 years, when the orbit of this swarm and that of the Earth intersect in a real point.

From these data the elongation of the radiant from the Earth's apex is found to be

$$\epsilon = 113^\circ{\cdot}73,$$

and hence the relative velocity of the swarm in its node is equal to 0·53 of the Earth's orbital velocity at the same time; in astronomical units

$$\log w = 7{\cdot}9592$$

This gives for Δz_0 the enormous value $11^\circ{\cdot}70$! But the radiant of this swarm also never sets in the latitude of Greenwich. In the same way as in the former example, I find the following values of z, Q, Δz, $\Delta\alpha$ and $\Delta\delta$ for every three hours of the hour angle t from $t=0$ to $t=24^h$.

TABLE II.

t	z	Q	Δz	$\Delta\alpha$	$\Delta\delta$	T
h	°	°	°	°	°	h
0	8·4	0·0	− 0·86	0·00	+ 0·86	15
3	31·1	58·4	− 3·25	+ 3·80	+ 1·71	18
6	57·7	47·4	− 6·45	+ 6·65	+ 4·36	21
9	76·7	26·8	− 9·28	+ 5·72	+ 8·26	0
12	85·4	0·0	− 10·80	0·00	+ 10·80	3
15	76·7	26·8	− 9·28	− 5·72	+ 8·26	6
18	57·7	47·4	− 6·45	− 6·65	+ 4·36	9
21	31·1	58·4	− 3·25	− 3·80	+ 1·71	12
24	8·4	0·0	− 0·86	0·00	+ 0·86	15

Fig. 2.

Fig. 2 illustrates this table. The attraction curve is here a very large oval, the undisturbed radiant being not inside but *outside* the curve, and *at a distance of about six degrees from its central point.*

II. *The Rotation of the Earth.*

1. *Perseids.*—This cause produces a small aberration of the radiant, never amounting to more than one degree in arc, at the latitude of Greenwich. The displacements $\Delta\alpha$, $\Delta\delta$ may be computed by means of the following formulæ, analogous to those used in the computation of the aberration of light.*

$$\Delta\alpha = -0^\circ\!.52 \cos t$$
$$\Delta\delta = -0.23 \sin t$$

whence I find the following table of corrections.

* These formulæ were first indicated by R. Lehman-Filhés in his *Inaugural-Dissertation: Zur Theorie der Sternschnuppen*, Berlin, 1878.

TABLE III.

t	$\Delta\alpha$	$\Delta\delta$	T
h	°	°	h
0	−0·52	0·00	6
3	−0·37	−0·17	9
6	0·00	−0·23	12
9	+0·37	−0·17	15
12	+0·52	0·00	18
15	+0·37	+0·17	21
18	0·00	+0·23	0
21	−0·37	+0·17	3
24	−0·52	0·00	6

This table is illustrated in Fig. 1 by the *aberration curve*—a small ellipse described by the radiant about its mean position.

2. *Andromedids.*—In the same way I find for the November shower

$$\Delta\alpha = -1^\circ{\cdot}45 \cos t$$
$$\Delta\delta = -0{\cdot}72 \sin t$$

which gives the following table of corrections :—

TABLE IV.

t	$\Delta\alpha$	$\Delta\delta$	T
h	°	°	h
0	−1·45	0·00	15
3	−1·03	−0·51	18
6	0·00	−0·72	21
9	+1·03	−0·51	0
12	+1·45	0·00	3
15	+1·03	+0·51	6
18	0·00	+0·72	9
21	−1·03	+0·51	12
24	−1·45	0·00	15

The small *aberration curve* in Fig. 2 illustrates the displacement of this radiant due to the rotation of the Earth.

III. *The Orbital Motion of the Earth.*

The orbital motion of the Earth plays a very important part in determining the position of the apparent radiant, provided that the observations of meteors belonging to the same shower extend over a long period of time. In fact, the apparent radiant is given by the direction of the diagonal constructed on the absolute velocities of the Earth and meteors respectively, but the directions of the tangents to the orbits described by the Earth and a meteoric swarm change every moment, and are widely different in different points of space; thus, if the meteor shower be very

extended, so that its meteors are seen during several successive days, or even weeks, the position of its apparent radiant must be different for each day. We shall now proceed to the computation of this most important part of the apparent displacement of radiants.

Two views may be taken *à priori* of the subject. First, a meteor shower may constitute a ring (or part of a ring) having a definite orbit in the solar system. In this case the elements ι, $\pi - \Omega$ (and ϕ if the orbit is an ellipse) are constant for all parts of the ring. Or, secondly, the meteor stream may be considered as the result of the disintegration of an agglomeration of independent cosmical particles which enter the solar system from external interstellar space*; in this case the elements of every portion of the stream must be different, whereas the heliocentric position of the aphelion or perihelion of the orbit is the same for every portion.

The first supposition—which will prove to be the true one at least in the case of the *Perseids*—leads to a very simple rule for the displacement of the apparent radiant of a meteoric ring, viz. :—

The latitude of the radiant remains constant, its longitude increases (approximately) *proportionally to time.*—In other words, if A be the longitude of the Earth's apex, then the quantities $l - A$, C are constant for every radiant—with a very small correction due to the eccentricity of the Earth's orbit; *i.e.* the radiant moves uniformly in a circle parallel to the ecliptic. The proof of this rule is very simple. It is known that the elements ι and $\pi - \Omega$ of a parabolic meteoric orbit are completely determined if the values of $l - A$ and C are given; and *vice versâ*, if ι and $\pi - \Omega$ are given and have constant values, the co-ordinates $l - A$, C must have constant values too. For elliptic orbits $l - A$, C and ϕ completely determine ι and $\pi - \Omega$; and conversely, ι, $\pi - \Omega$ and ϕ completely determine $l - A$ and C. Thus, in every case the radiant of a meteor-shower will move according to the rule given above.

This rule forms an excellent test both for the theory and for the observations. If a series of radiant points be given, belonging to the same meteoric shower, and observed during a long period of time, we have only to express their positions in longitude and latitude instead of in right ascension and declination, and to subtract from the longitude of each radiant the longitude of the Earth's apex at the same moment; *then all the radiants must coalesce in one point.*

Of course we cannot expect a perfect coincidence of all radiants after this operation; the inevitable errors of observation, the inaccurate method used in determining the position of the radiant points from observed meteor-paths, the neglected corrections due to the attraction and rotation of the Earth; all

* This view has been taken by Mr. Hoek in a paper published in the *Monthly Notices.*

these causes agree in displacing the observed radiant point from its true position, and the combined effect of these causes may, even in the more favourable case of a swarm like the *Perseids*, easily amount to several degrees.

The observations of Mr. Denning on the *Perseid* swarm extend over a period of almost six weeks (July 8–August 16). During this time the radiant describes, according to Mr. Denning, an arc extending *fifty-seven degrees* in right ascension and *ten degrees* in declination. The identification of points so distant from one another as one and the same radiant has been objected to; doubts have been expressed as to the possibility of a real connection between these different radiations, and more cogent reasons than the mere resemblance in the physical appearance of their meteors have been asked for.

Now if we perform on all the forty-nine radiants indicated in Mr. Denning's catalogue as belonging to the *Perseid* shower, the operations explained above, we obtain a result which supports Mr. Denning's (and our) view on these radiants even better than could be expected.

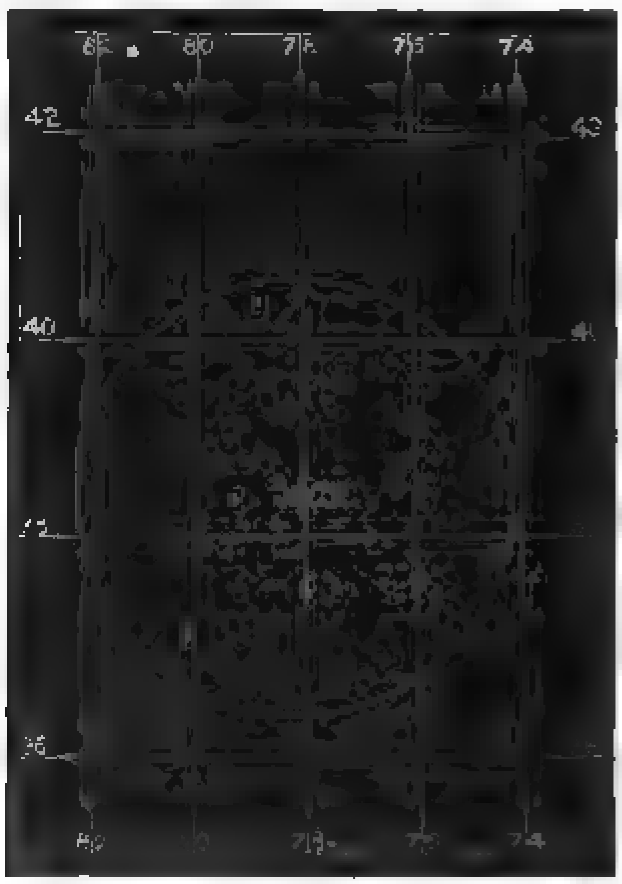


Fig. 3.

Fig. 3 shows the positions of all these radiants after the reduction,* *i.e.* after the parallactic correction has been applied

* I do not here give the details of the calculation as they are incorporated in the "Catalogue of Meteoric Orbits" appended to my Treatise *On the Determination of Orbits of Meteor-Showers*, St. Petersburg, 1891 (in Russian, with an abstract in English), on pp. 279–291. The ecliptical co-ordinates l, b of the radiants are given there, together with the differences $\odot' - l$, where $\odot' = A - 90°$. The fig. gives the positions of these points in the co-ordinates $\odot' - l$, b.

to them, together with the position of the cometary radiant. It will be seen that out of the forty-nine radiants *forty-six lie within a circle described about the cometary radiant with a radius of two degrees*, three only being outside this circle, and of these the two remotest at a distance of $4\frac{1}{2}^\circ$ and $3\frac{1}{2}^\circ$ respectively. These two last are precisely the first and last of the series; the first corresponding to July 8 and deduced from *five* meteor tracks only, and the last, on August 16, deduced from eight observations, and I hope that fresh data will bring them still nearer to the cometary radiant.*

It remains now to consider the real motion of a meteoric radiant as it results from the combined action of the three disturbing causes. The *parallactic curve* is drawn in Figs. 1 and 2, together with the two other curves described above, and the position of the radiant on it on three consecutive days is indicated. Combining the displacements due to the attraction and aberration of the radiant with its parallactic motion, I find, for the *Perseids* and *Andromedids*, the following positions on three consecutive days, and for every three hours of each day :—

TABLE V.

(*Perseids*) $\alpha_0 = 43^\circ{\cdot}58$ $\delta_0 = 57^\circ{\cdot}08$

	T	$\Delta\alpha_3$ $\Delta\alpha_1+\Delta\alpha_2$ parallactic	$\Sigma\Delta\alpha$	$\Delta\delta_3$ $\Delta\delta_1+\Delta\delta_2$	$\Sigma\Delta\delta$	Ultimate. α	Ultimate. δ
	h	° °	°	° °	°	°	°
Aug. 8	0	−2·01 +0·71	−1·30	−0·42+0·03	−0·39	42·28	56·69
	3	−1·85+0·95	−0·90	−0·39+0·41	+0·02	68	57·10
	6	−1·68+0·52	−1·16	−0·35+0·74	+0·39	42	47
	9	−1·51−0·23	−1·74	−0·32+0·75	+0·43	41·84	51
	12	−1·34−0·71	−2·05	−0·28+0·49	+0·21	53	29
	15	−1·17−0·80	−1·97	−0·24+0·20	−0·04	61	04
	18	−1·01−0·52	−1·53	−0·21−0·05	−0·26	42·05	56·82
	21	−0·84+0·08	−0·76	−0·18−0·14	−0·32	82	76
Aug. 9	0	−0·67+0·71	+0·04	−0·14+0·03	−0·11	43·62	97
	3	−0·51+0·95	+0·44	−0·11+0·41	+0·30	44·02	57·38
	6	−0·34+0·52	+0·18	−0·07+0·74	+0·67	43·76	75
	9	−0·17−0·23	−0·40	−0·04+0·75	+0·71	18	79
	12	0·00−0·71	−0·71	0·00+0·49	+0·49	42·87	57
	15	+0·17−0·80	−0·63	+0·04+0·20	+0·24	95	32
	18	+0·34−0·52	−0·18	+0·07−0·05	+0·02	43·40	10
	21	+0·51+0·08	+0·59	+0·11−0·14	−0·03	44·17	05

* The theoretical position of the cometary radiant on July 8 is $\alpha = 9^\circ$, $\delta = 46^\circ$; Mr. Denning's values are $\alpha = 3$, $\delta = 49$; also for August 16 our theory gives $\alpha = 54^\circ$, $\delta = 59^\circ$, while Mr. Denning finds from his observations $\alpha = 60^\circ$, $\delta = 59^\circ$.

	T	$\Delta\alpha_1$ $\Delta\alpha_1+\Delta\alpha_2$ parallactic	$\Sigma\Delta\alpha$	$\Delta\delta_1$ $\Delta\delta_1+\Delta\delta_2$	$\Sigma\Delta\delta$	Ultimate. α	δ
	h						
Aug. 10	0	+0°.67+0°.71	+1°.38	+0°.14+0°.03	+0°.17	44°.96	57°.25
	3	+0.84+0.95	+1.79	+0.18+0.41	+0.59	45.37	67
	6	+1.01+0.52	+1.53	+0.21+0.74	+0.95	11	58.03
	9	+1.17−0.23	+0.94	+0.24+0.75	+0.99	44.52	07
	12	+1.34−0.71	+0.63	+0.28+0.49	+0.77	21	57.85
	15	+1.51−0.80	+0.71	+0.32+0.20	+0.52	29	60
	18	+1.68−0.52	+1.16	+0.35−0.05	+0.30	74	38
	21	+1.85+0.08	+1.93	+0.39−0.14	+0.25	45.51	33
Aug. 11	0	+2.01+0.71	+2.72	+0.42+0.03	+0.45	46.30	53

Fig. 4 illustrates this table.

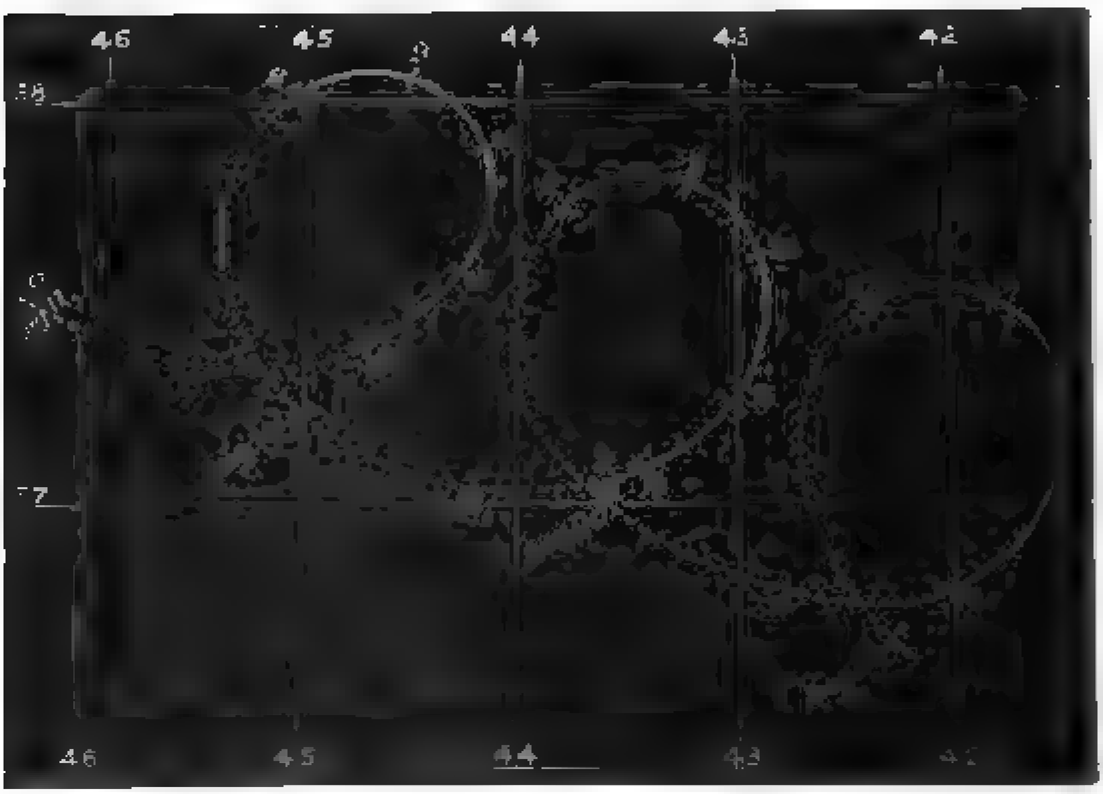


Fig. 4.

TABLE VI.

(*Andromedids*) $\alpha_0 = 23^\circ.27$ $\delta_0 = 43^\circ.12$

	T	$\Delta\alpha_1$ $\Delta\alpha_1+\Delta\alpha_2$ parallactic.	$\Sigma\Delta\alpha$	$\Delta\delta_1$ $\Delta\delta_1+\Delta\delta_2$	$\Sigma\Delta\delta$	Ultimate. α	δ
	h						
Nov. 26	0	−1°.62−4°.69	−6°.31	−0°.87 +8°.77	+7°.90	16°.96	51°.08
	3	−1.48−6.65	−8.13	−0.80 +5.08	+4.28	15.14	47.40
	6	−1.35−4.83	−6.18	−0.72 +2.22	+1.50	17.09	44.62
	9	−1.22−1.45	−2.67	−0.65 +0.86	+0.21	20.60	43.33
	12	−1.08+2.73	+1.65	−0.58 +1.20	+0.62	24.52	43.78
	15	−0.94+6.65	+5.71	−0.51 +3.64	+3.13	28.98	46.25
	18	−0.81+6.75	+5.94	−0.44 +7.55	+7.11	29.21	50.23
	21	−0.68+1.45	+0.77	−0.36+10.80	+10.44	24.04	53.56

	T	$\Delta\alpha_3$ parallactic	$\Delta\alpha_1+\Delta\alpha_2$	$\Sigma\Delta\alpha$	$\Delta\delta_3$	$\Delta\delta_1+\Delta\delta_2$	$\Sigma\Delta\delta$	Ultimate. α	δ
	h	°	°	°	°	°	°	°	°
Nov. 27	0	−0·54	−4·69	−5·23	−0·29	+8·77	+8·48	18·04	51·60
	3	−0·40	−6·65	−7·05	−0·22	+5·08	+4·86	16·22	47·98
	6	−0·27	−4·83	−5·20	−0·14	+2·22	+2·08	18·07	45·20
	9	−0·14	−1·45	−1·59	−0·07	+0·86	+0·79	21·68	43·91
	12	0·00	+2·73	+2·73	0·00	+1·20	+1·20	26·00	44·32
	15	+0·14	+6·65	+6·79	+0·07	+3·64	+3·71	30·06	46·83
	18	+0·27	+6·75	+7·02	+0·14	+7·55	+7·69	30·29	50·81
	21	+0·40	+1·45	+1·85	+0·22	+10·80	+11·02	25·12	54·14
Nov. 28	0	+0·54	−4·69	−4·15	+0·29	+8·77	+9·06	19·12	52·18
	3	+0·68	−6·65	−5·97	+0·36	+5·08	+5·44	17·30	48·56
	6	+0·81	−4·83	−4·02	+0·44	+2·22	+2·66	19·25	45·78
	9	+0·94	−1·45	−0·51	+0·51	+0·86	+1·37	22·76	44·49
	12	+1·08	+2·73	+3·81	+0·58	+1·20	+1·78	27·08	44·90
	15	+1·22	+6·65	+7·87	+0·65	+3·64	+4·29	31·14	47·41
	18	+1·35	+6·75	+8·10	+0·72	+7·55	+8·27	31·37	51·39
	21	+1·48	+1·45	+2·93	+0·80	+10·80	+11·60	26·20	54·72
Nov. 29	0	+1·62	−4·69	−3·07	+0·87	+8·77	+9·64	20·20	52·76

Fig. 5 illustrates this table.

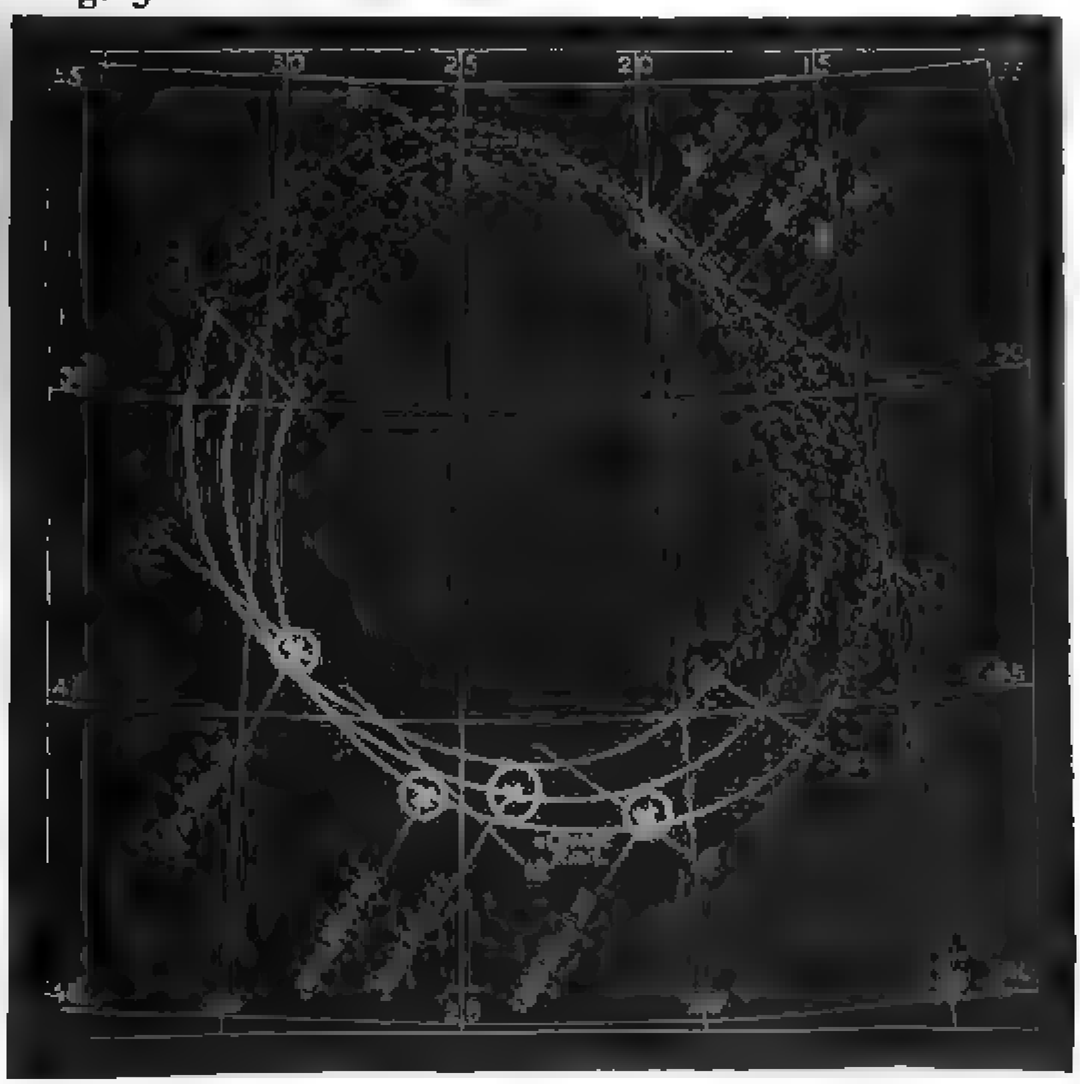


Fig. 5.

It may now be seen how difficult and complicated a problem it is to find a radiant point from a series of observations of meteor tracks extending over some length of time.

The accurate method would be the following:—

From a few meteor paths traced on a celestial chart an approximate position of the radiant is to be found; from this the three corrections should be determined for every observation of a meteor; the corrected paths of the meteors again mapped, and then a more accurate position of the radiant may be found.

On the large Sun-spot of 1892 February 5–18, and the Associated Magnetic Disturbance.

(*Communicated by the Astronomer Royal.*)

As the large spot seen on the Sun 1892 February 5–18 was the largest which has been photographed at Greenwich, and as its presence appears to have been associated with a great magnetic disturbance, some particulars may be of interest, though they must necessarily be imperfect pending the arrival of photographs from India and Mauritius to supplement the Greenwich series.

At Greenwich photographs of the Sun were obtained on five days during the first appearance of the group, viz. on February 5, 13, 16, 17, and 18; and up to the present time on three days during its second appearance, viz. on March 5, 7, and 8. The following table gives the heliographic coordinates of the centre of the great spot, and the total area of the entire group, expressed in millionths of the Sun's visible hemisphere, for each day of observation during its first appearance:—

Date. G. Civil T.		Distance from Centre in terms of Sun's Radius.	Position-Angle from Sun's Axis.	Heliographic Longitude from Central Meridian.	Heliographic Longitude from Prime Meridian.	Latitude.	Area. Umbra.	Area. Whole Spot.
	h m		°	°	°	°		
Feb. 5	10 24	0·985	118·4	−81·9	259·0	−29·0	96	1522
13	9 47	0·488	217·5	+19·8	255·6	−29·2	451	2999
16	9 40	0·859	248·4	+58·5	254·9	−28·1	256	2288
17	12 10	0·938	241·3	+70·4	252·3	−29·3	139	1433
18	11 58	0·986	240·6	+82·5	251·3	−30·1	84	1389

The great spot was on the central meridian February 11, 22^h G.C.T. On February 13, when the group was best seen, being then nearer the centre of the disc than on any of the other days of observation, the group extended in heliographic longitude from 270° to 245°, a length of 25°; and in heliographic latitude

from 23° S. to 33° S., a breadth of 10°. The principal spot of the group had a length of 14°, from 263° to 249°, and a breadth of 8°, from 25° S. to 33° S.

The group had greatly diminished in area when it reappeared on the east limb on March 5.

The following table gives the position of the principal spot and area of the entire group, as observed up to the present time, during its second appearance:—

Date. G. Civil T.		Distance from Centre in terms of Sun's Radius.	Position-Angle from Sun's Axis.	Heliographic Longitude from Central Meridian	Heliographic Longitude from Prime Meridian.	Latitude.	Area. Umbra.	Area. Whole Spot.
	h m		°	°	°	°		
Mar. 5	9 51	0·927	118·3	−68·4	250·9	−28·8	28	208
7	9 54	0·714	124·0	−42·4	250·4	−28·9	34	510
8	10 39	0·571	132·8	−28·5	250·8	−29·2	35	521

It will be seen that the group has greatly diminished in area during the fortnight in which it was on the further side of the Sun. There seems, however, a slight tendency to increase again, especially with regard to the principal spot, the area of which rose from 101 on March 5 to 369 and 448 on March 7 and 8. The great spot has undergone but little change of place during the interval, for its latitude has remained practically unchanged, and though its longitude, as computed with a sidereal period of 25·38 days, appears to show a slight diminution, this is due to the rotation period of the Sun being longer for high latitudes, the rotation period adopted corresponding to a latitude of about 15°.

A great magnetic disturbance, accompanied by an aurora, occurred on 1892 February 13–14, commencing about a day after the large spot was on the central meridian of the Sun's disc. The following particulars have been drawn up by Mr. Ellis:—

The magnetic disturbance commenced in all elements on February 13 at 5^h 32^m, Greenwich Civil Time, by a sudden increase of declination, horizontal force, and vertical force, accompanied by strong manifestation of earth currents. Large motions were registered in all elements; between February 13, 19^h, and February 14, 3^h, they were unusually large, amounting to more than 1° in declination, the trace having passed off the sheet for one hour shortly after midnight. In horizontal force the disturbance exceeded 0·029 of the whole horizontal force, the trace having similarly passed off the sheet for nearly half an hour at about 22^h, and afterwards for more than 1½ hours from shortly before 1^h to $2\frac{1}{2}^h$. In vertical force the disturbance was also great, the trace having gone off the sheet in the direction of increasing force from $14\frac{1}{2}^h$ to 19^h, and in the direction of decreasing force from $0\frac{1}{2}^h$ to 2^h; the motion probably exceeded 0·020 of the whole vertical force. The disturbance ceased on the evening of

February 14. An aurora was seen at Greenwich between 0^h and 1^h, by Mr. McClellan.

The disturbance compares in magnitude with those of 1882 April and November, the registered motions being large in all elements on all three occasions. The disturbance of 1882 November was, however, extreme, the motions then registered being apparently in excess even of those of 1882 April and 1892 February.

The following table shows how the recent disturbance compares with previous ones recorded since the commencement of the Greenwich series of solar photographs in 1873.

Particulars of Magnetic Disturbances from the Photographic Registers at the Royal Observatory, Greenwich.

Period of Disturbance. Greenwich Civil Time.	Character of Disturbance.	Extreme amplitude of Motion during Disturbance. Declination.	Horizontal Force.	Vertical Force.
h h		° ′		
1880 Aug. 12 12 to Aug. 14 8	*c*	1 5	·016	·008
1881 Jan. 31 12 „ Feb. 1 3	*c*	1 15	·018	·008
Sept. 12 12 „ Sept. 14 2	*c*	1 0	·017	·008
1882 Apr. 16 23 „ Apr. 17 23	*g*	1 0+	·030+	·022+
Apr. 20 3 „ Apr. 21 8	*g*	1 10+	·020+	·008
Oct. 2 10 „ Oct. 3 3	*c*	1 0	·014	no register
Nov. 17 10 „ Nov. 21 4	*g*	1 50	·050+	·025
Nov. 21 15 „ Nov. 22 0	*m*	0 40	·010	·003
1883 Sept. 16 3 „ Sept. 17 17	*c*	0 50	·019	·005+
1884 July 2 19 „ July 4 6	*c*	0 40	·018	·007
Oct. 1 22 „ Oct. 3 6	*m*	0 30	·010	·004
Nov. 2 13 „ Nov. 3 8	*m*	0 45	·012	·005
1885 Mar. 15 10 „ Mar. 16 6	*c*	0 55	·010	·009
1886 Mar. 30 8 „ Apr. 1 3	*c*	1 5	·020+	·007
1892 Feb. 13 5 „ Feb. 14 18	*g*	1 10+	·029+	·015+

In the column "Character of Disturbance" *m* indicates moderate; *c*, considerable; and *g* great.

The amplitudes in the case of Horizontal Force and Vertical Force are given in parts of these forces respectively.

The sign + attached to a measure indicates that the spot of light passed beyond the limit of registration.

Most of these magnetic disturbances occurred when an exceptionally large spot was visible on the Sun near the centre of the disc, or about the time of some great change in a Sun-spot.

Royal Observatory, Greenwich:
1892 *March* 11.

Addendum.

Since this note was drawn up, Mr. Maunder has found, from an examination of the photographs at Greenwich, that this Sun-spot appeared on the Sun on 1891 November 15, when it came into view close to the east limb as a spot of considerable size. It was also photographed at its appearances in December 1891 and January 1892, so that it has persisted through five rotations, with, however, a remarkable progressive drift in latitude from about 17° S. to 30° S. Several magnetic disturbances have occurred during its presence on the Sun, three being subsequent to that on February 13, described above, viz.: March 1^d 0^h to 16^h (moderate), 0° 45′ in declination; March 6^d 9^h to 7^d 9^h (considerable), 0° 50′ in declination; March 11^d 10^h to 13^d 5^h (great), 1° 15′ in declination.

Royal Observatory, Greenwich:
1892 *March* 25.

On the Photographic Magnitude of Nova Aurigæ, as Determined at the Royal Observatory, Greenwich. By W. H. M. Christie, M.A., F.R.S., Astronomer Royal.

A telegram notifying the receipt by Dr. Copeland of an anonymous postcard, which announced the discovery of a new star in *Auriga*, was received at Greenwich at about 5 P.M. on Feb. 1, and a few hours afterwards Mr. Criswick obtained a photograph of the Nova with the 13-inch photographic telescope. Photographs of the new star have been taken at every available opportunity since, with exposures ranging from 15^s to 12^m, and the diameters of the images of the Nova and of certain comparison stars have been measured under the microscope with a filar micrometer, with a view to determining the changes in photographic magnitude of the Nova. Independently of this special object, the discussion has a general interest in relation to the problem of determining the magnitudes of stars for the photographic chart.

On each plate the diameters of the images of the Nova, of four Argelander stars (B.D. + 30°, Nos. 944, 949, 938, and 913), ranging from 8·2 to 8·7 mag. (Argelander), and of a 5·7 mag. star (B.D. + 30° 898), were measured, and the magnitude of the Nova was inferred from those of the comparison stars by means of the formula

$$m = 2{\cdot}5(\log t - 0{\cdot}97\sqrt{d}) + \text{const.}$$

given in the *Monthly Notices*, vol. lii., p. 146, the measures of the comparison stars being used to determine the value of the constant for each plate. The magnitudes of the four 8–9 mag.

stars were taken from Argelander, and that of B.D. + 30° 898 from the *Harvard Photometry* and the *Uranometria Oxoniensis.*

The measures were made independently by Miss Everett and Miss Rix, some of the plates being also measured by myself, and the results obtained by each measurer have been kept separate, as there is decided evidence of personality. The values of the constant obtained from the measures of the four 8–9 mag. stars and of the 5·7 mag. star respectively, are also exhibited separately (as c_1 and c_2), with the values of the magnitude of the Nova, deduced by means of the mean values of c_1 and c_2 for the two or three exposures on each plate. As a rule, each measurer made four measures of each image of the Nova and of the 5·7 mag. star, and two measures of each image of each of the four 8–9 mag. stars.

The 5·7 mag. star, B.D. + 30° 898, is about 1° from the centre of the plate, and the image is somewhat diamond shaped. In this and other similar cases two diameters at right angles have been measured, and the geometric mean taken.

The results are tabulated below.

The initials AE, ER, and WC are those of Miss Everett, Miss Rix, and Mr. Christie respectively.

MAGNITUDES OF NOVA AURIGÆ, 1892.

Derived from comparison with four small stars, mag. 8·2, 8·2, 8·7, 8·7.

Date and Exposure.	Value of c_1.			Magnitude of Nova.		
	AE.	ER.	WC.	AE.	ER.	WC.
Feb. 1.		No. 247.	*Ilford Plate.*	Photogr. Mr. Criswick.		
7^m	10·22	10·30	10·23	4·29	4·60	4·53
Feb. 2.		No. 249.	*Ilford Plate.*	Photogr. Mr. Davidson.		
3^m	9·09	...	...	4·05	...	...
2^m	8·88	..	...	4·21	...	...
1^m	9·19	...	...	3·85	...	...
Mean	9·05			4·04		
Feb. 2.		No. 250.	*Ilford Plate.*	Photogr. Mr. Davidson.		
8^m	8·44	...	...	3·69	...	...
6^m	8·43	...	...	3·60	...	...
Mean	8·434			3·64		
Feb. 2.		No. 251.	*Lumière Plate.*	Photogr. Mr. Davidson.		
12^m	9·76	9·65	...	2·98	2·67	...
30^s	9·30	9·01	...	3·76	3·51	...
15^s	9·46	9·03	...	3·56	3·25	...
Mean	9·51	9·23		3·43	3·14	

Date and Exposure.	Value of c_1. AE.	ER.	WO.	Magnitude of Nova. AE.	ER.	WO.
Feb. 3.		No. 255.	*Lumière Plate.*	Photogr. Mr. Furner.		
4^m	9·11	8·65	...	3·90	3·49	...
2^m	9·13	8·66	...	3·77	3·84	...
1^m	9·20	8·91	...	3·32	3·71	...
Mean	9·15	8·74		3·66	3·68	
Feb. 3.		No. 256.	*Lumière Plate.*	Photogr. Mr. Furner.		
8^m	8·59	8·24	...	3·35	3·54	...
6^m	8·51	8·00	...	3·75	3·82	...
Mean	8·55	8·12		3·55	3·68	
Feb. 3.		No. 257.	*Lumière Plate.*	Photogr. Mr. Furner.		
12^m	8·49	8·28	8·52	3·84	2·82	3·68
30^s	8·88	8·48	8·57	3·79	3·27	3·66
15^s	8·98	8·49	8·77	3·77	3·14	3·46
Mean	8·77	8·42	8·61	3·80	3·08	3·60
Feb. 12.		No. 262.	*Lumière Plate.*	Photogr. Miss Everett.		
12^m	9·14	8·72	8·83	4·28	3·75	3·82
30^s	9·20	8·50	8·43	4·38	3·32	3·45
15^s	9·59	8·74	8·71	4·08	3·37	3·12
Mean	9·28	8·65	8·65	4·25	3·48	3·46
Feb. 12.		No. 263.	*Lumière Plate.*	Photogr. Miss Everett.		
8^m	8·82	8·86	...	4·19	4·18	...
Feb. 13.		No. 264.	*Ilford Plate.*	Photogr. Mr. Criswick.		
8^m	8·48	8·50	...	4·20	4·23	...
6^m	8·71	8·42	...	4·12	4·31	..
Mean	8·60	8·46		4·16	4·27	
Feb. 13.		No. 265.	*Ilford Plate.*	Photogr. Mr. Criswick.		
12^m	8·61	8·04	...	4·18	4·26	...
30^s	8·45	7·96	...	4·83	4·43	...
15^s	8·53	7·89	...	4·98	4·53	...
Mean	8·53	7·96		4·66	4·41	

Date and Exposure.	Value of c_1.			Magnitude of Nova.		
	AE.	ER.	WO.	AE.	ER.	WO.
Feb. 13.		No. 267.	*Ilford Plate.*	Photogr. Mr. Criswick.		
4m	8·29	7·66	...	4·43	3·98	...
2m	8·33	7·76	...	4·71	4·23	...
1m	8·46	7·71	...	4·56	4·23	...
Mean	8·36	7·71		4·57	4·15	
Feb. 18.		No. 271.	*Ilford Plate.*	Photogr. Mr. Criswick.		
12m	9·20	9·39	...	3·64	2·96	...
30s	9·03	9·11	...	3·99	3·86	...
15s	8·98	8·52	...	4·04	3·83	...
Mean	9·07	9·01		3·89	3·55	
Feb. 18.		No. 273.	*Ilford Plate.*	Photogr. Mr. Criswick.		
4m	9·13	9·14	...	4·04	3·89	...
2m	9·35	9·26	...	4·19	3·87	...
1m	9·26	9·25	...	4·04	3·89	...
Mean	9·24	9·22		4·09	3·88	
Feb. 22.		No. 275.	*Mawson & Swan Plate.*	Photogr. Miss Rix.		
12m	9·61	...	...	3·97	...	...
30s	9·79	...	...	4·72	...	...
15s	9·70	...	...	4·90	...	...
Mean	9·70			4·53		
Feb. 22.		No. 277.	*Mawson & Swan Plate.*	Photogr. Miss Rix.		
4m	9·90	...	...	5·23	...	...
2m	10 20	...	...	4·96	...	...
1m	9·80	...	...	5·18	...	...
Mean	9·96			5·12		
Mar. 7.		No. 279.	*Mawson & Swan Plate.*	Photogr. Miss Everett.		
12m	8·97	...	...	4·62	...	...
30s	9·00	...	...	5·29	...	...
15s	8·49	...	...	5·37	...	...
Mean	8·82			5·09		

Date and Exposure.	Value of c_1.			Magnitude of Nova.		
	AE.	ER.	WC.	AE.	ER.	WC.
Mar. 7.		No. 280.	*Mawson & Swan Plate.*	Photogr. Miss Russell.		
4^m	8·37	...	...	4·99	...	...
2^m	8·36	...	...	5·21	...	...
1^m	8·29	...	...	4·81	...	...
Mean	8·34			5·00		
Mar. 9.		No. 283.	*Ilford Plate.*	Photogr. Miss Everett.		
12^m	8·77	...	...	6·01	...	...
30^s	8·90	...	...	6·21	...	...
15^s	9·23	...	...	6·08	...	...
Mean	8·96			6·10		

Derived from comparison with a star, B. D. + 30° 898, mag. 5·7.

Date and Exposure.	Value of c_2.			Magnitude of Nova.		
	AE.	ER.	WC.	AE.	ER.	WC.
Feb. 1.		No. 247.	*Ilford Plate.*	Photogr. Mr. Criswick.		
7^m	...	...	...	...	...	...
Feb. 2.		No. 249.	*Ilford Plate.*	Photogr. Mr. Davidson.		
3^m	9·58	...	...	4·59	...	...
2^m	9·33	...	...	4·75	...	...
1^m	9·90	...	...	4·39	...	...
Mean	9·60			4·58		
Feb. 2.		No. 250.	*Ilford Plate.*	Photogr. Mr. Davidson.		
8^m	8·85	...	...	4·38	...	...
6^m	9·40	...	...	4·30	...	...
Mean	9·13			4·34		
Feb. 2.		No. 251.	*Lumière Plate.*	Photogr. Mr. Davidson.		
12^m	10·80	10·62	...	4·18	3·96	...
30^s	10·55	10·37	...	4·96	4·74	...
15^s	10·78	10·48	...	4·76	4·54	...
Mean	10·71	10·49		4·63	4·41	
Feb. 3.		No. 255.	*Lumière Plate.*	Photogr. Mr. Furner.		
4^m	9·38	8·63	...	4·30	3·42	...
2^m	9·58	8·65	...	4·17	3·77	...
1^m	9·68	8·73	...	3·72	3·64	...
Mean	9·55	8·67		4·06	3·61	

Date and Exposure.	Value of c_2. AE.	ER.	WC.	Magnitude of Nova. AE.	ER.	WC.
Feb. 3.	No. 256.	*Lumière Plate.*		Photogr. Mr. Furner.		
8^m	8·95	8·45	...	3·83	3·70	...
6^m	9·10	8·10	...	4·23	3·98	...
Mean	9·03	8·28		4·03	3·84	
Feb. 3.	No. 257.	*Lumière Plate.*		Photogr. Mr. Furner.		
12^m	8·90	9·15	9·35	4·41	3·69	4·71
30^s	9·48	9·13	9·63	4·36	4·14	4·69
15^s	9·63	9·58	9·93	4·34	4·01	4·49
Mean	9·34	9·29	9·64	4·37	3·95	4·63
Feb. 12.	No. 262.	*Lumière Plate.*		Photogr. Miss Everett.		
12^m	9·33	9·05	9·28	4·54	4·49	4·88
30^s	9·45	9·58	9·73	4·64	4·06	4·51
15^s	9·83	9·53	10·13	4·34	4·11	4·18
Mean	9·54	9·39	9·71	4·51	4·22	4·52
Feb. 12.	No. 263.	*Lumière Plate.*		Photogr. Miss Everett.		
8^m	9·15	9·45	...	4·52	4·77	...
Feb. 13.	No. 264.	*Ilford Plate.*		Photogr. Mr. Criswick.		
8^m	9·45	9·15	...	5·12	4·75	...
6^m	9·58	8·80	...	5·04	4·83	...
Mean	9.52	8·98		5·08	4·79	
Feb. 13.	No. 265.	*Ilford Plate.*		Photogr. Mr. Criswick.		
12^m	9·60	8·70	...	5·20	5·07	...
30^s	9·48	8·78	...	5·85	5·24	...
15^s	9·58	8·83	...	6·00	5·34	...
Mean	9·55	8·77		5·68	5·22	
Feb. 13.	No. 267.	*Ilford Plate.*		Photogr. Mr. Criswick.		
4^m	9·53	8·60	...	5·58	4·71	...
2^m	9·48	8·20	...	5·86	4·96	...
1^m	9·53	8·53	...	5·71	4·96	...
Mean	9·51	8·44		5·72	4·88	

Date and Exposure.	Value of e_r. AE.	ER.	WC.	Magnitude of Nova. AE.	ER.	WC.
Feb. 18.		No. 271.	*Ilford Plate.*	Photogr. Mr. Criswick.		
12ᵐ	10·00	10·40	...	4·56	4·34	...
30ˢ	10·05	10·53	...	4·91	5·24	...
15ˢ	9·93	10·23	...	4·96	5·21	...
Mean	9·99	10·39		4·81	4·93	
Feb. 18.		No. 273.	*Ilford Plate.*	Photogr. Mr. Criswick.		
4ᵐ	8·90	8·95	...	3·94	3·77	...
2ᵐ	9·23	9·10	...	4·09	3·75	...
1ᵐ	9·28	9·25	...	3·94	3·77	...
Mean	9·14	9·10		3·99	3·76	
Feb. 22.		No. 275.	*Mawson & Swan Plate.*	Photogr. Miss Rix.		
12ᵐ	10·58	...	...	4·96	...	...
30ˢ	10·70	...	...	5·71	...	...
15ˢ	10·78	..	...	5·89	...	...
Mean	10·69			5·52		
Feb. 22.		No. 277.	*Mawson & Swan Plate.*	Photogr. Miss Rix.		
4ᵐ	9·93	...	...	5·36	...	...
2ᵐ	10·53	...	...	5·09	...	...
1ᵐ	9·80	...	...	5·31	...	...
Mean	10·09			5·25		
Mar. 7.		No. 279.	*Mawson & Swan Plate.*	Photogr. Miss Everett.		
12ᵐ	9·88	...	...	5·25	...	...
30ˢ	9·28	...	...	5·92	...	...
15ˢ	9·25	...	...	6·00	...	...
Mean	9·45			5·72		
Mar. 7.		No. 280.	*Mawson & Swan Plate.*	Photogr. Miss Russell.		
4ᵐ	8·53	...	...	5·32	...	...
2ᵐ	8·65	...	...	5·54	...	...
1ᵐ	8·83	...	...	5·13	...	...
Mean	8·67			5·33		

Date and Exposure.	Value of c_2. AE.	ER.	WC.	Magnitude of Nova. AE.	ER.	WC.
Mar. 9.		No. 283.	*Ilford Plate.*	Photogr. Miss Everett.		
12^m	9·38	...	...	6·45	...	...
30^s	9·18	...	...	6·65	...	...
15^s	9·63	...	...	6·52	...	...
Mean	9·40			6·54		

In the values of the constant deduced by each measurer there appear to be no systematic differences between the long exposures and the short, and the mean of the values for the two or three exposures on each plate has therefore been used as the value of the constant for the plate. The range of exposures from 15^s to 12^m, representing 4·2 magnitudes, corresponds approximately to the difference in photographic magnitude between the Nova and the 8–9 mag. comparison stars. It may here be explained that the constant c represents the magnitude of the star which, with an exposure t^s, would give a diameter d'' for the photographic image, such that $\log t - 0·97\sqrt{d} = 0$, or $\log t = 0·97\sqrt{d}$. The following are the values of the exposure in seconds required to give the corresponding diameters of image for stars of magnitude $= c$.

Diameter.	Exposure.	Diameter.	Exposure.
"	s	"	s
1	9·3	3	47·9
$1\frac{1}{2}$	15·4	4	87·1
2	23·5	5	147·6

Thus, if we take the value of the constant c_1, found for Photo. 247 on February 1, we should have a star of 10·25 mag. photographed in $15\frac{1}{2}^s$ with a diameter of $1\frac{1}{2}''$, which may be considered to give a distinctly measurable disc. It will be seen that the values of the constant on different nights and with different plates differ considerably, so that in some cases we should only get stars of $8\frac{1}{4}$ mag. photographed, instead of $10\frac{1}{4}$ mag., with an exposure of $15\frac{1}{2}^s$. The values of c_2 are generally greater than those of c_1, implying that the star B.D. + 30° 898 is photographically brighter than 5·7 mag., if we take the four 8–9 mag. stars as our standard. The photographic magnitude of B.D. + 30° 898 thus deduced from the mean of all the measures is 5·04, the difference between the determinations by Miss Everett and Miss Rix respectively being only 0·03 mag.

Both in the values of the constant (c_1 and c_2) and in the deduced magnitudes of the Nova (m_1 and m_2) there is decided evidence of personality between Miss Everett and Miss Rix, the mean values of AE—ER being

in c_1 + 0·34 mag.; in m_1 + 0·27 mag.; in c_2 + 0·39 mag.; in m_2 + 0·33 mag.

The close correspondence between the values of the personality in c_1 and m_1, and in c_2 and m_2, respectively, would imply that the difference in the deduced magnitudes of the Nova results mainly from personality in the measurement of the comparison stars. This inference is supported by a comparison of my own results with Miss Everett's, though mine are hardly numerous enough to give any trustworthy determination of personality. The mean values found for AE − WC are

in c_1 + 0·35 mag.; in m_1 + 0·39 mag.; in c_2 − 0·24 mag.; in m_2 − 0·14 mag.

The values for AE − ER for the corresponding exposures being

in c_1 + 0·43 mag.; in m_1 + 0·59 mag.; in c_2 + 0·10 mag.; in m_2 + 0·36 mag.

The following table exhibits the magnitude of the Nova for each day, deduced from all the measures of each observer by comparison with the four 8–9 mag. stars, and with the 5·7 mag. star, respectively, the number of images of the Nova measured being indicated by the suffix; and the means for all the observers on each day. In forming these means it has been thought better not to apply any correction for personality, which must necessarily be subject to much uncertainty; but to take the simple mean of all the results by each observer, with weights proportional to the number of images of the Nova measured. The means m_1 and m_2 are formed from the comparisons with the four 8–9 mag. stars and the 5·7 mag. star respectively, and the final means in the last column are the means of m_1 and m_2, after applying a correction of − 0·66 mag. to the latter, to make them comparable, this being the difference between the assumed magnitude for this star (5·7) and that deduced from the photographs relatively to the four 8–9 mag. stars—viz., 5·04 mag.

Photographic Magnitude of Nova Aurigæ from comparisons with four stars 8–9 mag. with B.D. + 30° 898.

								Means Adopted.		
		AE.	ER.	WC.	AE.	ER.	WC.	m_1	m_2	
1892.		mag.	mag.	mag.	mag.	mag.	mag.	mag.	mag.	Mag.
Feb.	1	$4{\cdot}29_1$	$4{\cdot}60_1$	$4{\cdot}53_1$	...	...	...	4·47	...	4·47
	2	$3{\cdot}71_8$	$3{\cdot}14_3$	...	...	$4{\cdot}41_2$	...	3·55	4·50	3·70
	3	$3{\cdot}69_8$	$3{\cdot}45_9$	$3{\cdot}60_3$	$4{\cdot}17_8$	$3{\cdot}79_8$	$4{\cdot}63_3$	3·57	4·08	3·50
	12	$4{\cdot}23_4$	$3{\cdot}66_4$	$3{\cdot}46_2$	$4{\cdot}51_4$	$4{\cdot}36_4$	...	3·81	4·44	3·80
	13	$4{\cdot}50_8$	$4{\cdot}28_8$	...	$5{\cdot}55_8$	$4{\cdot}98_8$	...	4·39	5·27	4·50
	18	$3{\cdot}99_6$	$3{\cdot}72_6$	...	$4{\cdot}35_6$	$4{\cdot}40_6$	...	3·86	4·38	3·79
	22	$4{\cdot}83_6$	...	...	$5{\cdot}39_6$	...	...	4·83	5·39	4·78
Mar.	7	$5{\cdot}05_6$	...	...	$5{\cdot}53_6$	...	...	5·05	5·53	4·96
	9	$6{\cdot}10_6$	...	...	$6{\cdot}54_6$	...	...	6·10	6·54	5·99

It would seem from these results that the Nova brightened decidedly from February 1 to February 3, when it was at its maximum; and that after diminishing considerably in brightness it attained a secondary maximum about February 18, since which date it has become gradually fainter. Unfortunately, owing to cloudy weather, the record is very imperfect. It will be remarked that the Nova appears to be much brighter photographically than it is to the eye, judging from the visual estimations of magnitude which have been published.

Royal Observatory, Greenwich:
1892 *March* 11.

Preliminary Note on the Magnitude of the New Star in Auriga.

Communicated by Professor C. Pritchard, D.D., F.R.S.

Observations of the magnitude of the new star in *Auriga* have been made at this Observatory on all available occasions, and the results are here presented to the Society. The determinations of magnitude have been made to depend both on photometric measures with the wedge photometer and on photographs taken with the 13-inch photographic telescope.

The Nova has been compared with the following stars, whose magnitudes have been assumed from the *Uranometria Nova Oxoniensis*:

χ Aurigæ	mag.	5·08
ϕ Aurigæ	„	5·44
26 Aurigæ	„	5·63
Lal. 10143	„	5·84

The results of the comparisons with the wedge photometer are shown in the following table:

Date 1892.	Observed Photometric Magnitude.	Stars of Comparison.
Feb. 3	4·82	χ Aurigæ.
5	5·11	χ, ϕ Aurigæ.
7	4·96	χ, ϕ, 26 Aurigæ.
11	5·16	ϕ, 26 Aurigæ.
13	5·28	ϕ, 26 Aurigæ.
16	5·44	χ, ϕ Aurigæ.
18	5·60	ϕ, 26 Aurigæ, Lal. 10143.
22	5·51	26 Aurigæ, Lal. 10143.
28	5·64	ϕ, 26 Aurigæ.
Mar. 7	5·89	Lal. 10143.

A series of photographs has likewise been taken of the Nova and of the neighbouring stars. The magnitude has been deduced, after measurement of the diameter of the photographic image, by means of a curve drawn in the manner suggested in the *Proceedings of the Royal Society*, May, 1886. This curve is based on the diameters of stars ranging from *β Tauri* (mag. 1·79) to *Piazzi* v. 62 (mag. 6·20).

Photographic Magnitude of Nova Aurigæ.

Date 1892.	Photographic Magnitude.
Feb. 11	5·09
13	5·35
16	5·39
18	5·70
Mar. 7	5·82

P.S.—The following further determinations of the magnitude of the Nova have been made since the date of this paper :—

	By Wedge Photometer. mag.	By Photographic Record.
Mar. 8	5·96	
12	6·93	7·13
13	7·07	
14	7·25	
18	8·76	8·93
19	9·10	9·26
22	9·32	

Oxford University Observatory:
1892 *March* 23.

The New Star in Auriga. By George Knott, B.A., LL.B.

The new star in *Auriga* was first seen here on the evening of February 3, when it appeared to be equal in magnitude to *χ Aurigæ*. As seen in the telescope its colour was yellowish. Viewed with a small direct-vision spectroscope, which fits over the field-lens of an ordinary negative eye-piece, mag. power 200, its spectrum was seen to be crossed by four broad bright lines in the green and blue. Lettering these in order from green to blue, *b* was in mid-distance between *a* and *d*, and *c* was at about one-third of the distance from *d* to *b*. The brightest of the four lines was *d* (solar F?), and *c* was the narrowest and faintest. On receiving, later in the evening, Dr. Copeland's Edinburgh Circular, I looked for other bright lines, and glimpsed one in the violet.

The red end of the spectrum was very bright, but I failed to distinguish C, perhaps owing to want of definition in this part of the spectrum. On February 5 the four bright lines in the green and blue were again well seen, the order of brightness appearing to be *d b c a*. A faint bright line was seen in the violet, and one in the yellow or orange, and C was perhaps doubtfully distinguishable. On February 13 the order of brightness was noted *d, a b, c.*

The weather has been very unfavourable here for observation, but I give below my magnitude estimates of the new star. They were made with a binocular field-glass, mag. power 5, and the magnitudes of the comparison stars, χ and 26 *Aurigæ* and L 10143, were adopted from Professor Pritchard's *Uranometria Nova Oxoniensis*. The light of the new star would seem to have been subject to slight fluctuations, but perhaps these may be in part due to errors of observation.

	Mag.		Mag.
Feb. 3	5·1	Feb. 23	5·9
5	5·1	25	5·6
7	5·1	27	5·6
11	5·1	28	5·5
12	5·1	29	5·7
13	5·3	Mar. 5	5·8
20	5·8	7	6·1
22	5·9		

The star D.M. +30° 913, 8·7 mag., precedes the new star $1^m\ 51^s{\cdot}05$, $7''{\cdot}68$ N. There is an 11·0 mag. star in the *nf* quadrant, measures of which relative to the new star were taken in position and distance with a filar micrometer on two nights with the following results:—

	Pos.	Dist.	Epoch.
	32·18°	80·28″	1892·134
	31·88	80·31	1892·178
Means	32·03	80·29	1892·16

A reduction of these coordinates gives as the place of the 11·0 mag. star relative to the new star $\Delta\alpha + 3^s\ 29$, $\Delta\delta + 68''\ 07$.

From an observation on the meridian on February 20, I found the approximate Mean Right Ascension of the new star for 1892·0 to be $5^h\ 25^m\ 3^s{\cdot}33$. The colour of the new star has been noted by me to be pale yellow, or pale yellow with a slight tinge of orange.

Knowles Lodge, Cuckfield:
1892 *March* 9.

Note on the Spectrum of Nova Aurigæ. By E. W. Maunder.

The appearance of the new star discovered by Dr. Anderson near χ *Aurigæ* happened at a most unfortunate time for spectroscopic observation at the Greenwich Observatory, since the old $12\frac{3}{4}$ inch refractor had been dismounted some months, and its successor, the 28-inch, had not come to hand. There was, therefore, at the time no telescope available to which either of the spectroscopes of the Observatory could be applied. Under these circumstances the best course appeared to be to try and utilise the object-glass prism presented to the Observatory by Sir Henry Thompson, and the Astronomer Royal directed me to attach it to the 9-inch photographic telescope which the same donor had also given. As, however, that telescope had been employed for a different work, and as, therefore, the prism had never been tested with it, several serious difficulties were encountered, and, partly owing to the delays thus caused, and partly to the continued cloudy weather, which greatly hindered the work of adjustment, it was not until February 18 that any exposure could be made upon the Nova, and this was rendered useless by the cloudy state of the sky. On February 22 an exposure was, however, made more successfully, though two serious drawbacks prevented the photograph being a sharp one. The first difficulty was that the telescope-tube was not long enough to get a good focus, and the second that the enormous weight of the Lassell telescope, to which the Thompson instrument is attached, causes it to flex to a marked amount when off the meridian, and hence the star can with difficulty be made to preserve the same position in declination during a long exposure, and of course any drift in declination must be fatal to the definition of the lines.

The plate, to which an exposure of 70 minutes was given, however, shows the more pronounced lines in the spectrum, though, for the reasons above mentioned, their definition is only poor. A preliminary measurement and reduction of the photograph give the following positions for the lines :—

Line.	Bright lines.	Dark lines.
	4919	
F	4860	
	4629	
	4580	
	4547	
	4510	
	4472	
G	4340	4316

Line.	Bright lines.	Dark lines.
	4229	4212
	4174	4155
h	4101	4085
H	3968	3953
K	3933	3913
α	3887·5	
β	3834	

The bright lines due to hydrogen were recognised by their correspondence in position with the dark lines in the spectrum of *β Tauri*, which was photographed in close proximity to that of the Nova, and Dr. Huggins's values have been adopted for their wave-lengths. The positions of the other bright lines, and of the dark lines, have been computed from the measures by the use of an interpolation formula.

The mean displacement of the dark lines relative to the corresponding bright lines was 18·3 tenthmetres, and corresponds to a motion of relative approach of 820 miles a second. This is probably a considerably exaggerated value, the want of fine definition in the photograph rendering the measures necessarily rough, and tending to exaggerate the measures of displacement.

On the same evening, and with the same instrument, I succeeded in obtaining a view of the visual part of the spectrum. A positive eye-piece of magnifying power about 80 was used. The spectrum was bright, and five bright lines were seen in the green, one in the orange, one in the extreme red, and two lines between these two last named. Other bright lines were also seen in the blue, but these were clearly those seen in the photograph.

Of the lines in the green, the first was clearly the F line; and the second, proceeding in the direction of the less refrangible rays, was the line measured on the photograph as at λ 4919.

Adopting the interval between these two lines as unity, that between the second and third was estimated as about 1·4 (for, of course, no measures could be made), between the third and fourth as 2·4, and between the fourth and fifth as 2·0. This would make the fifth line not far from E, the fourth line near *b*, but further towards the blue, and the third line very near the chief nebular line. So rough an estimation, of course, leaves it quite an open question as to whether these lines really coincided with the lines named or not. The line supposed to be near E appeared to be a diffused band, rather than a sharply defined line.

The line in the extreme red, supposed to be C, was very bright; the line in the orange, supposed to be D, was less so; the two which lay between C and D were less bright.

This occasion, February 22, was the only one in which I have had the opportunity of examining or photographing the spectrum

of the Nova, and the instrument referred to, the Thompson photographic telescope, aperture 9 inches, with a prism of 15° before the object-glass, was the only instrument I was able to employ.

Blackheath:
1892 *March* 11.

Photograph of the Region of Nova Aurigæ. By Isaac Roberts, F.R.S.

The region of *Nova Aurigæ*, with R.A. 5^h 25^m, and Decl. + 30° 21′ as the centre, was photographed with the 20-inch reflector on the night of February 5, which was the first night with a clear interval, after the receipt of the Edinburgh Circular No. 22 announcing the discovery. Since that date the photographs described in the sequel have been taken.

The photograph now presented is an enlargement to the scale of one centimetre to four minutes of arc from a negative taken on February 18 with an exposure of three hours. The plate was so placed in the reflector that the star D.M. No. 899, Zone 30°, mag. 6·2, should be simultaneously photographed with the Nova, and on two plates the star 26 *Aurigæ* was photographed with the Nova.

The photographs obtained have been examined by aid of the pantograver, and the photo-images of the Nova, of D.M. No. 899, and of 26 *Aurigæ* measured to 0·0001 of an inch diameter. The results are given in the following table:—

Table of measured Photo-diameters.

Date when Negative was taken.	Duration of exposure of Negative.	Diameter of Nova.		Diameter of D. M. No. 899, Zone 30 degrees.		Diameter of 26 Aurigæ.	
		In parts of an inch.	In seconds of arc.	In parts of an inch.	In seconds of arc.	In parts of an inch.	In seconds of arc.
1892.			″		″		″
Feb. 5	45^m	0·0169	34·9	0·0174	35·9	...	...
13	15^m	·0137	28·3	...	...	0·0142	29·3
13	5^m	·0128	26·5	...	...	·0127	26·3
18	3^h	·0217	44·7	·0203	41·9	...	...
22	20^m	·0137	28·1	·0152	31·4	...	...
22	5^m	·0130	26·8	·0146	30·0	...	...
25	5^m	·0130	26·8	·0147	30·2	...	...
25	20^m	·0142	29·3	·0144	29·7	...	...

The following observations upon the appearance of the photo-image of the Nova and of the comparison stars were made during the examination of the negatives under a magnifying power of 24 diameters.

February 5, exposure 45 min.: the image of the Nova is not as well defined at the margin as that of the star D.M. No. 899.

February 13, exposures 15 min. and 5 min. respectively: the image of the Nova is fairly well defined round the margin on each of the photographs.

February 18, exposure 3 hours: the margins of both the Nova and the comparison star No. 899 are nebulous and undefined. There are six stars visible round the Nova, within a radius distance of 50 secs. of arc, and there are also twelve stars round No. 899 within a radius of 50 secs.

The four negatives taken on February 22 and 25 show both the Nova and star No. 899 with well-defined margins, the exposures being respectively 5 mins. and 20 mins.

It will be observed, on examination of the table of the measured diameters of the Nova and the comparison stars, that no decided change in the brightness of the Nova has taken place during the interval between February 5 and 25, if we adopt the photo-images with 20 mins. exposure on the 25th as the standard; but if we adopt the image formed with 5 mins. exposure, there would be shown a fading of the light of the Nova between February 18 and 25.

Photograph of the Region of Nova Cygni. By Isaac Roberts, F.R.S.

Nova Cygni was discovered by Dr. J. F. J. Schmidt at Athens on 1876 November 24, and its co-ordinates for 1878 are given R.A. $21^h\ 36^m\ 55^s$, Decl. $+42^\circ\ 17'\cdot9$. Between that date and the year 1882 many observations concerning the Nova are recorded, but I shall refer only to the catalogue and chart by Drs. Copeland and Lohse, published in vol. ii. of *Copernicus*. These give clear evidence of great care exercised by the observers and delineators in their preparation; and by their aid and the photographs now presented we are enabled to infer that several changes in the stars have taken place during the past ten years.

Two photographs are before us which are enlargements from a negative taken on 1891 September 27, with an exposure of 2 hours in the 20-inch reflector; one of them is enlarged to the scale of one centimetre to four minutes of arc; the other is to the same scale as the chart of the region of the Nova referred to above, which scale is one centimetre to one second of arc.

On the chart is drawn a circle enclosing a space fifteen minutes of arc in diameter, with the Nova as the centre, and I have drawn with pencil on the photograph a line enclosing a space very nearly coincident with that of the chart; we are thus enabled to make comparisons of the two with little trouble. By inspection we soon observe that changes have taken place in the brightness of some of the stars, and also some changes in

their relative positions; but I do not intend to discuss these in great detail for the reason that Dr. Copeland will probably re-survey this region with the aid of the instruments employed by him in the first survey. I will therefore now only refer to a few of the most conspicuous changes in the stars which the photograph indicates.

The stars on the chart catalogue are numbered from 1 to 113, and their magnitudes, position-angle, distance, co-ordinates, and other particulars are given. On the large-scale photograph I have numbered with white ink the stars corresponding with them, to which I will now refer. The Nova is within the white circle.

List of the Stars which have undergone conspicuous change since the year 1878.

No. 2	star,	12·2	mag. on chart,	is about	14	mag.	on photograph.
6	„	14·0	„	„	16	„	„
12	„	11·8	„	„	13	„	„
18	„	12·6	„	„	15	„	„
21	„	11·8	„	„	13	„	„
30	„	11·4	„	„	14	„	„
46	„	13·0	„	„	12	„	„

No. 47 is on the photograph a double star, the *comes* being about 14th mag.

The Nova is not given on the chart, but on the photograph it is a prominent object as a star of about 13th mag.

No. 84 star has moved in position-angle from *np* star No. 86 to *n*.

No. 99 star on the chart is single, but on the photograph it is double.

No. 104 star on chart is 11·4 mag., and on the photograph is about 13th mag.

No. 105 star is single on chart, and double on the photograph.

Some of the changes in magnitude which have been indicated may be due, of course, to the well-known differences between eye estimations and photographic diameters, but this only emphasises the necessity of repeating the eye observations, and also, after a sufficient interval of time has elapsed, taking other photographs of the region.

On an Annual Variation in the R–D Discordance.
By H. H. Turner, M.A., B.Sc.

In connection with a discussion of the distribution of temperature in the Transit Circle Room at the Royal Observatory, Greenwich, it occurred to me to inquire whether the R–D discordance varies during the year. Such a variation might be an indication of the dependence of part, or the whole, of the discordance upon the temperature distribution. The major part of the discordance is usually ascribed to flexure of the instrument; and in the case of the Greenwich Transit Circle the closeness with which the law of the sine zenith-distance satisfies the observations certainly points to the probability of this hypothesis. But there is a curious anomaly in the fact that whereas the horizontal flexure thus indicated would be nearly 1″, observations made with the collimators in the ordinary way give a very small horizontal flexure.

It has further been noticed that the residuals of R–D, after comparing the actual observations with this assumed simple law, are persistent in sign year after year at the same zenith-distance, and suggest a secondary discordance not included in the assumed formula. The R–D may in fact be a complex phenomenon, and part of it at least may be due to other causes than flexure. This remark will now be illustrated by a discussion of the residuals for the years 1883–1890, during which the principal (flexure) term of the R–D has remained sensibly constant. Previously to 1883 the range of stars available in reflexion observations was much more restricted, owing to the mounting of the collimators, and the results are thus not so readily comparable. In the years 1883–1890 the results have been grouped in as nearly as possible the same manner; and the mean of the residuals for corresponding groups is given opposite the approximate mean Z. D. of the group.

Mean Residuals of R–D for Years 1883–1890.

Mean. Z.D.	North Stars.	South Stars.	N–S.	Mean Z.D.	North Stars.	South Stars.	N–S.
$68\frac{1}{2}$°	+0″.40	−0″.83	+1″.23	36°	+0″.24	+0″.36	−0″.12
$65\frac{1}{2}$	+0.36	−0.24	+0.60	30	+0.05	+0.38	−0.33
62	−0.24	−0.32	+0.08	26	+0.03	+0.25	−0.22
59	−0.55	−0.18	−0.37	24	0.00	+0.07	−0.07
56	−0.25	−0.28	+0.03	20	+0.02	+0.08	−0.06
52	+0.18	−0.0	+0.24	$16\frac{1}{2}$	+0.06	...	...
48	+0.02	−0.06	+0.08	$12\frac{1}{2}$	+0.18	−0.22	+0.40
42	+0.31	+0.18	+0.13	$9\frac{1}{2}$	+0.23	...	...

From accurate measurements recently made, it appears that in reflexion observations made at zenith-distances less than 21° or greater than 62° the full aperture of the telescope objective is not used, and hence the corresponding groups should be excluded from the present discussion. From the intermediate groups it will be seen that both for N. and S. stars the residuals are negative for large zenith-distances and positive for small, though the change takes place earlier for N. stars than for S. A smooth curve shows a secondary discordance amounting to at least $0''\cdot5$ not included in the standard formula. It is under consideration whether this discordance may not be due to the fact that the direct and reflected rays do not strike the general mass of air in the observing room at the same point, and may suffer different refractions: the difference possibly varying with the time of year.

But the immediate object of the present note is to point out that the R—D discordance is subject to an annual fluctuation, whatever the cause. For this purpose little more is necessary than to print the following table of results, obtained as follows:— The whole of the observations 1883–1890 were collected and divided into groups according to the month of the year, retaining the cross grouping in zenith-distance; in fact, the subdivision into twelve months is merely substituted for that into eight years, so that we have in each monthly group about two-thirds of the number of stars formerly found in each annual group, and the material for determining the R—D for any month is comparable with that usually employed for the annual determination. In one or two cases where there was no star in a particular group, a mean value for that group has been adopted from neighbouring groups, and the result enclosed within brackets.

Mean R−D Discordance for each Calendar Month in the Years 1883–1890.

North Stars.

Mean N.P.D. of Group.	Mean Z.D. of Group.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
° ′	° ′	″	″	″	″	″	″	″	″	″	″	″	″
−29·0	−67·30	+0·06	−0·94	−1·04	−1·67	−0·75	−1·06	−1·56	−0·80	−0·38	−0·57	−0·23	−0·44
−27·0	−65·30	−0·97	−0·90	−1·38	−1·24	−1·11	−1·03	−0·96	−0·73	−3·43	−0·77	−0·54	−0·58
−25·0	−63·30	−1·63	−1·55	−1·11	−1·20	−2·22	−2·15	−1·22	−1·45	−1·03	−1·04	−1·35	−1·05
−23·0	−61·30	(−1·62)	−0·90	−1·27	−1·82	−1·30	−1·79	−1·67	−1·23	−0·47	−1·02	−0·86	+1·31
−20·30	−59·0	−1·60	−1·89	−1·82	−1·75	−2·03	−1·87	−0·89	−0·93	−1·11	−1·67	−1·48	−1·67
−17·0	−55·30	−1·58	−0·38	−0·64	−1·27	−1·38	−1·45	−1·47	−1·16	−1·01	−1·53	−1·04	−1·24
−13·0	−51·30	−0·52	−1·12	+1·35	−1·01	−0·44	−1·03	−1·28	−0·45	−0·91	−1·01	−0·48	−1·09
− 8·30	−47·0	−1·50	−1·08	−1·02	−1·29	−1·57	−0·80	−1·81	-0·73	−0·63	−0·96	−0·61	−0·66
− 3·0	−41·30	+0·01	−0·22	−0·88	−0·12	−0·35	−0·77	−0·54	−0·53	−0·42	−0·46	−0·58	−0·48
+ 3·0	−35·30	−0·11	−0·38	−0·01	−1·53	−0·57	−0·92	−0·76	−0·94	−0·69	−0·40	−0·52	−0·86
+ 8·30	−30·0	−0·09	−0·51	−0·45	−0·29	−0·78	−0·47	−0·36	−0·72	−0·43	−0·50	−0·46	−0·85
+14·0	−24·30	−0·68	+0·19	+0·07	−0·46	−1·01	−0·65	−0·51	−0·33	−0·75	−0·88	−0·56	−0·36
+18·30	−20·0	−0·78	+0·28	+0·37	−0·76	−1·38	−1·12	−0·87	−0·54	−0·59	+0·15	−0·68	−0·30
+22·0	−16·30	+0·63	+0·47	−0·44	−0·62	−0·39	−0·55	−0·45	−0·47	−0·13	−0·46	−1·04	−0·03
+25·0	−13·30	−0·53	+0·19	−0·12	−0·04	−0·47	−0·73	−0·14	+0·45	−0·06	+0·31	−0·45	−0·68
+33·0	− 5·30	−0·48	+0·84	+0·15	−0·12	−0·48	−0·33	+1·95	−0·09	−0·04	+0·20	+0·36	+0·41

South Stars.

Mean N.P.D. of Group.	Mean Z.D. of Group.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
° ′	° ′	″	″	″	″	″	″	″	″	″	″	″	″
+ 46·0	+ 7·30	+0·52	+0·71	−0·54	+2·72	−0·34	+0·99	+0·66	+0·22	−0·79	+0·23	−0·38	−0·51
+ 57·0	+18·30	+0·42	−1·04	+0·78	+0·52	+0·17	+0·30	+0·78	+0·30	+0·49	+0·22	+0·23	+1·17
+ 62·30	+24·0	−0·27	+0·95	+0·47	−0·03	−0·05	+0·84	+0·49	+0·37	−0·46	+0·59	+0·05	+0·31
+ 65·30	+27·0	+0·67	−0·12	+0·06	+0·41	+0·50	−0·16	+0·57	+0·08	+0·09	+0·48	+0·20	+0·01
+ 68·30	+30·0	+0·44	+0·12	+0·11	+0·69	+0·32	−0·91	+0·49	+0·35	+0·25	+0·98	−0·10	+0·13
+ 72·0	+33·30	+0·34	+0·32	+0·18	+0·58	+0·19	+0·37	−0·11	+0·31	+0·13	+0·36	+0·48	+0·27
+ 76·0	+37·30	+1·42	+0·06	+0·07	+0·16	+0·69	+0·52	+0·57	+0·42	+0·54	+0·05	+0·23	+0·19
+ 81·0	+42·30	+0·20	+0·19	+0·29	+0·66	+0·46	+0·94	+1·12	+0·61	+0·53	+0·41	+0·73	+0·41
+ 86·0	+47·30	+0·42	+0·71	+0·96	+0·97	+1·29	+0·73	+1·04	+0·37	+0·44	+0·72	+1·28	+1·41
+ 90·0	+51·30	+0·75	+0·77	+0·52	+1·09	+1·39	+0·78	+0·98	+1·54	+0·87	+1·01	+0·87	+0·56
+ 94·0	+55·30	+0·25	+0·98	+0·55	+0·74	+0·95	+1·97	+1·45	+1·23	+1·07	+1·95	+1·13	+0·96
+ 97·30	+59·0	+0·22	+0·83	+1·64	+1·51	+1·38	+1·14	+1·35	+0·66	+0·64	+1·62	+1·39	+2·44
+100·15	+61·45	+0·47	+1·14	+0·86	+1·59	+1·30	+1·53	+1·32	+1·72	+1·08	+1·46	+0·61	+1·44
+103·15	+64·45	−0·02	+1·42	+1·53	+1·82	+1·98	+1·53	+1·23	+1·15	+1·05	−0·09	+0·76	(+0·63)
+107·0	+66·30	+1·83	+2·19	+1·95	+1·99	+2·12	+2·40	+2·26	+1·63	+1·54	+1·15	+1·34	−0·17

If we assume the expression $a + b \sin$ Z. D. for the discordance, and determine by least squares the values of a and b for each month, we obtain the following values:—

	a	b
	$''$	$''$
January	−0·01	+0·97
February	−0·01	+0·93
March	−0·01	+1·13
April	−0·04	+1·29
May	−0·11	+1·49
June	−0·09	+1·47
July	−0·07	+1·37
August	−0·06	+1·22
September	−0·04	+1·14
October	−0·06	+1·12
November	0·00	+1·09
December	−0·04	+0·99

Showing a well-marked inequality in b of 0″·6. The cause of this inequality is at present the subject of further investigation.

The Apparent Places of Close Polar Stars.
By A. M. W. Downing, M.A.

In the *Monthly Notices*, vol. l., pp. 357–359, Mr. Turner calls attention to certain discordances in the apparent places of polars, as given in the different Ephemerides for 1891 and some preceding years. As modifications have been introduced both into the *Connaissance des Temps* and into the *Nautical Almanac* since the publication of Mr. Turner's note, I have thought that it would be worth while communicating to the Society the results of comparisons of the apparent right ascensions of *Polaris*, λ *Ursæ Minoris*, and σ *Octantis*, as given in the *Connaissance des Temps* and *Nautical Almanac* for 1894, as well as of the apparent right ascensions of the two first-named stars as given in the *Berliner Jahrbuch* and in the *American Ephemeris*, with those of the *Nautical Almanac* for the same year. As the *Berliner Jahrbuch* for 1894 had not reached me when this work was undertaken, the method of procedure followed was to compare the places in the *Berliner Jahrbuch* for 1893 with those of the *Connaissance des Temps* for the same year, and from the results of the comparison of the places in the latter publication with those of the *Nautical Almanac* for 1894 to deduce the differences of places of the *Berliner Jahrbuch* and of the *Nautical Almanac*. It may be remarked that no change was

made, either in the *Connaissance des Temps* or the *Berliner Jahrbuch*, in the adopted methods of computing apparent places of polars in 1894, so that the results obtained from a comparison of the places for 1893 may be assumed to hold good for 1894 also. In all these comparisons the effect of difference of longitude of the meridians for which the computations of the different Ephemerides were made has been taken into account.

In 1894 an important modification was introduced into the *Nautical Almanac*—viz., terms of the second order in the "star-corrections" have been taken into account in the cases of the close polar stars by the method proposed by Fabritius (*Ast. Nachrichten*, Nos. 2072 and 2073), the form adopted being the very convenient one given by Oppolzer in his *Traité de la détermination des Orbites*, p. 264:—

$$\alpha - \alpha_0 = \Delta\alpha_0 + \tan\delta_0 \,\Delta\alpha_0\, \Delta\delta_0 \sin 1'',$$
$$\delta - \delta_0 = \Delta\delta_0 - \tfrac{1}{2}\cot\delta_0\, \Delta\alpha_0^2 \sin 1'',$$

where α_0, δ_0 are the mean values of the coordinates for the beginning of the year. This method is also adopted in the *Connaissance des Temps*, and the same terms of nutation being used in it and in the *Nautical Almanac*, the agreement between the "star-corrections" for polars ought now to be very close, as in fact it will be seen to be by reference to the tables of comparisons given below. The difference in the adopted value of the precession constant gives rise principally, of course, to a discordance proportional to the time (as does also a difference in the adopted proper motion), and is well marked in the case of the places of *Polaris*.

In both the *Berliner Jahrbuch* and the *American Ephemeris* the corrections due to the effect of the terms of a higher order than the first are computed from the ordinary formulæ, somewhat similar expressions being used in both publications. In the *Berliner Jahrbuch* the same terms of nutation are employed as in the *Connaissance des Temps* and *Nautical Almanac*; whilst in the *American Ephemeris* several additional terms are taken into account.

Most of these have very small coefficients, and in the present state of astronomy may perhaps be safely neglected. One pair of terms, however, with argument $(2\odot - \Omega)$, seem to make their effect very sensible in the comparison between the *Nautical Almanac* and the *American Ephemeris*, giving rise to an inequality with period of about six months, which is apparent both in the case of *Polaris* and in that of λ *Ursæ Minoris*. The terms in question are—

$$\text{In obliquity} \quad -0''.0067 \cos(2\odot - \Omega);$$
$$\text{In longitude} \quad +0.0125 \sin(2\odot - \Omega);$$

and these might perhaps be introduced into the expressions for

the "Day Numbers" in the other Ephemerides also with advantage.

The tables given below require very little explanation. A "group" is the mean of ten days (except, of course, Group xxxvii.), and the differences are the actual differences corrected only for longitude, where this correction is sensible. These mean differences have been plotted down, and curves drawn, where it appeared necessary, to guide the eye in estimating the periodic discordances. The agreement between the *Connaissance des Temps* and the *Nautical Almanac* is practically complete, the greatest discordance—viz. $0^s{\cdot}05$ for λ *Ursæ Minoris*—being in arc of a great circle $\frac{\cdot 05 \times 15}{56}$, or $0''{\cdot}01$. The periodic discordances between the *Berliner Jahrbuch* and the *Nautical Almanac* (which seem to be clearly enough indicated, although the quantities are so small) may be due to difference in the method of correcting for second order terms, for, as stated above, the same terms of nutation (as well as the same constant of precession) are employed in the computations in each case. The discordances existing between the *American Ephemeris* and the *Nautical Almanac* may be partly due to the same cause, but in their more marked features they are probably to be ascribed to the effect of the additional terms of nutation adopted in the *American Ephemeris*, which have been referred to above.

The amount of Fabritius' correction for *Polaris* and λ *Ursæ Minoris* is also exhibited graphically for every tenth day throughout the year 1894, in order to enable the reader to form an estimate of its magnitude and variation during the course of a year. It will be remarked that, although the horizontal scale is the same, the vertical scale in this case is only one-tenth of what it is in the comparisons of the stars' right ascensions.

Generally, the close agreement of the "star-corrections" for these polars, as given in the different Ephemerides, will be remarked, as well as the great improvement that has taken place in this respect during the last few years.

Right Ascensions of Polaris.

Group.	N. A.—C. T. 1894.	N. A.—A. E. 1894.	C. T.—B. J. 1893.
	s	s	s
I.	+0·049	−1·398	−1·167
II.	+0·059	−1·396	−1·178
III.	+0·064	−1·390	−1·183
IV.	+0·067	−1·407	−1·182
V.	+0·070	−1·432	−1·180
VI.	+0·071	−1·438	−1·170
VII.	+0·079	−1·455	−1·168
VIII.	+0·080	−1·443	−1·156
IX.	+0·082	−1·433	−1·145

Group.	N. A.−C. T. 1894. s	N. A.−A. B. 1894. s	C. T.−B. J. 1893. s
X.	+0·081	−1·446	−1·154
XI.	+0·085	−1·425	−1·163
XII.	+0·090	−1·407	−1·149
XIII.	+0·092	−1·406	−1·145
XIV.	+0·089	−1·406	−1·140
XV.	+0·092	−1·400	−1·154
XVI.	+0·093	−1·370	−1·154
XVII.	+0·095	−1·381	−1·138
XVIII.	+0·095	−1·398	−1·151
XIX.	+0·097	−1·397	−1·166
XX.	+0·093	−1·390	−1·144
XXI.	+0·095	−1·389	−1·147
XXII.	+0·095	−1·381	−1·166
XXIII.	+0·098	−1·416	−1·157
XXIV.	+0·100	−1·420	−1·162
XXV.	+0·100	−1·415	−1·163
XXVI.	+0·100	−1·424	−1·171
XXVII.	+0·101	−1·427	−1·183
XXVIII.	+0·100	−1·400	−1·173
XXIX.	+0·104	−1·402	−1·184
XXX.	+0·101	−1·407	−1·205
XXXI.	+0·104	−1·414	−1·190
XXXII.	+0·106	−1·394	−1·195
XXXIII.	+0·110	−1·384	−1·209
XXXIV.	+0·103	−1·391	−1·206
XXXV.	+0·108	−1·405	−1·208
XXXVI.	+0·108	−1·403	−1·216
XXXVII.	+0·110	−1·405	−1·225

Right Ascensions of λ Ursæ Minoris.

I.	−0·564	−1·032	+0·309
II.	−0·567	−1·042	+0·328
III.	−0·566	−1·015	+0·331
IV.	−0·563	−1·020	+0·319
V.	−0·562	−1·011	+0·319
VI.	−0·569	−1·027	+0·303
VII.	−0·574	−1·030	+0·303
VIII.	−0·575	−1·034	+0·295
IX.	−0·576	−1·041	+0·278

Group.	N. A.–C. T. 1894.	N.A.–A. R. 1894.	C. T.–R. J. 1893.
	s	s	s
X.	−0·577	−1·056	+0·281
XI.	−0·581	−1·041	+0·287
XII.	−0·584	−1·055	+0·275
XIII.	−0·589	−1·043	+0·274
XIV.	−0·592	−1·011	+0·292
XV.	−0·588	−1·012	+0·308
XVI.	−0·59	−1·012	+0·298
XVII.	−0·595	−1·010	+0·292
XVIII.	−0·597	−1·015	+0·311
XIX.	−0·602	−1·003	+0·327
XX.	−0·604	−1·032	+0·303
XXI.	−0·608	−1·038	+0·317
XXII.	−0·610	−1·032	+0·334
XXIII.	−0·599	−1·045	+0·329
XXIV.	−0·601	−1·040	+0·328
XXV.	−0·597	−1·020	+0·344
XXVI.	−0·597	−1·031	+0·350
XXVII.	−0·597	−1·018	+0·350
XXVIII.	−0·594	−1·000	+0·343
XXIX.	−0·594	−1·011	+0·345
XXX.	−0·586	−0·986	+0·353
XXXI.	−0·582	−0·986	+0·328
XXXII.	−0·584	−0·974	+0·315
XXXIII.	−0·576	−0·953	+0·341
XXXIV.	−0·577	−0·992	+0·317
XXXV.	−0·577	−0·979	+0·306
XXXVI.	−0·572	−0·975	+0·310
XXXVII.	−0·565	−1·007	+0·320

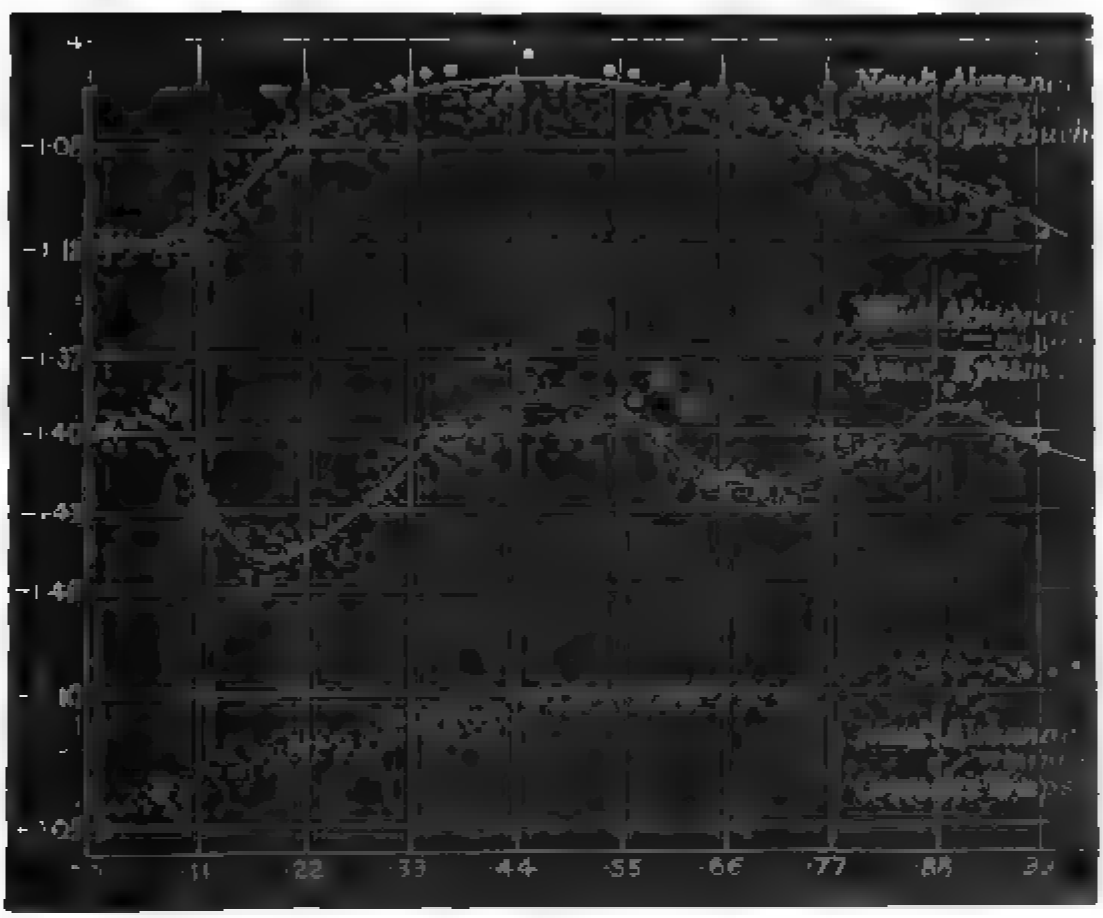
Right Ascensions of σ Octantis.

Group.	N. A.–C. T. 1894.	Group.	N. A.–C. T. 1894.
	s		s
I.	+0·133	VIII.	+0·136
II.	+0·124	IX.	+0·133
III.	+0·121	X.	+0·130
IV.	+0·127	XI.	+0·128
V.	+0·134	XII.	+0·137
VI.	+0·134	XIII.	+0·134
VII.	+0·126	XIV.	+0·124

Group.	N. A.—C. T. 1894.	Group.	N. A.—C. T. 1894.
	s		s
XV.	+0·126	XXVII.	+0·131
XVI.	+0·129	XXVIII.	+0·134
XVII.	+0·124	XXIX.	+0·135
XVIII.	+0·123	XXX.	+0·137
XIX.	+0·130	XXXI.	+0·140
XX.	+0·133	XXXII.	+0·142
XXI.	+0·122	XXXIII.	+0·145
XXII.	+0·127	XXXIV.	+0·143
XXIII.	+0·132	XXXV.	+0·152
XXIV.	+0·137	XXXVI.	+0·148
XXV.	+0·129	XXXVII.	+0·158
XXVI.	+0·130		

Right Ascensions of Polaris.

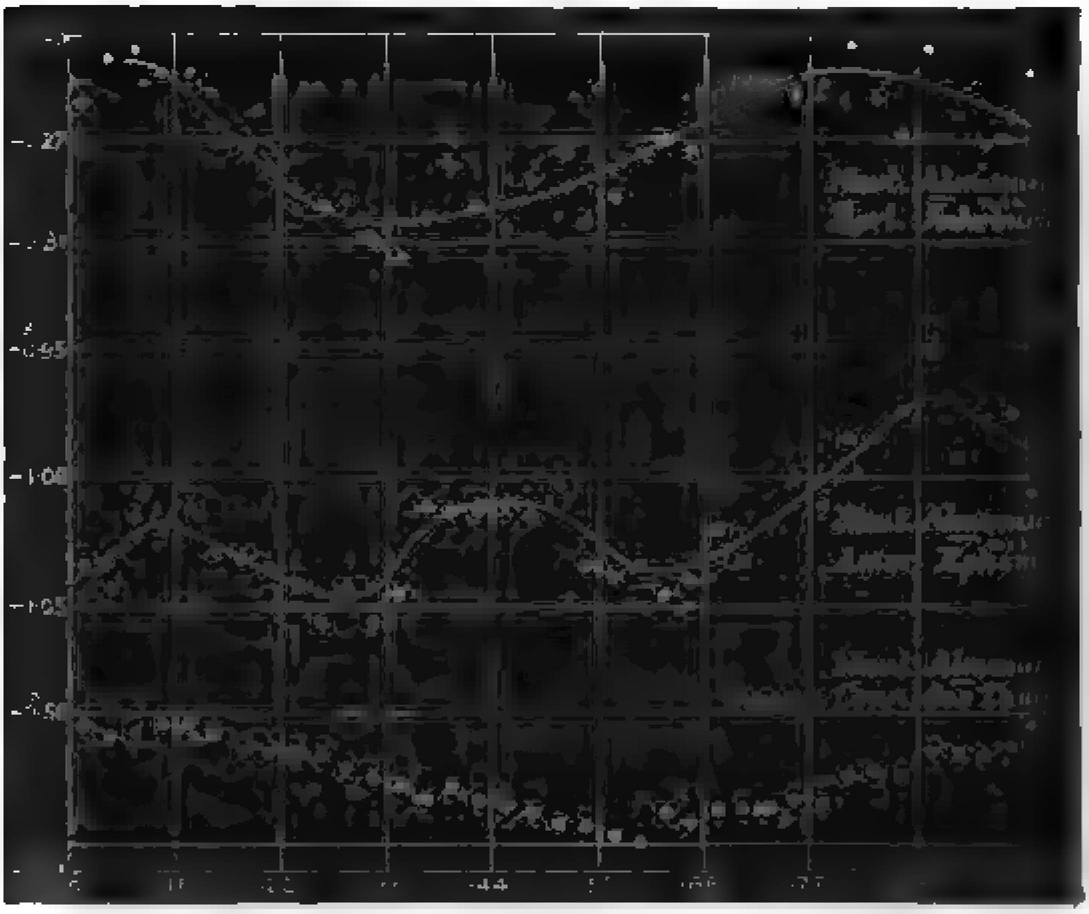
$\delta = 88^\circ\ 45'$, sec $\delta = 45{\cdot}8$.



The horizontal scale is fraction of the year.

Right Ascensions of λ Ursæ Minoris.

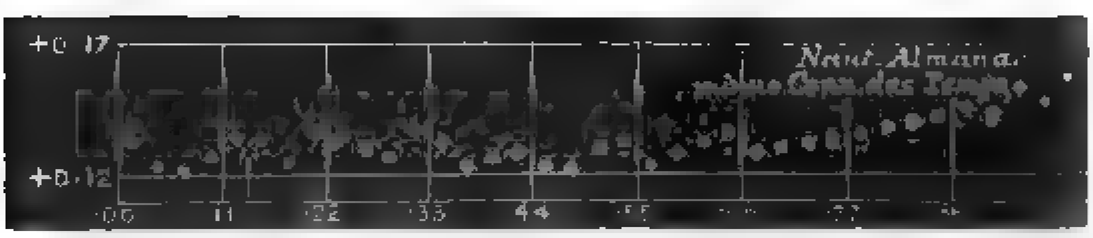
$\delta = 88° 59'$, sec $\delta = 56{\cdot}4$.



The horizontal scale is fraction of the year.

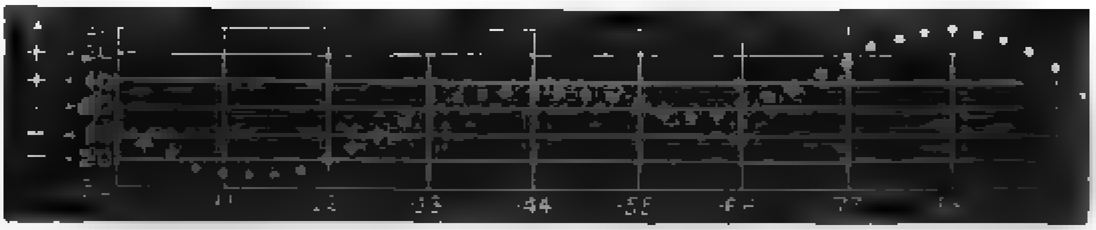
Right Ascensions of σ Octantis.

$\delta = 89° 16'$, sec $\delta = 78{\cdot}1$.



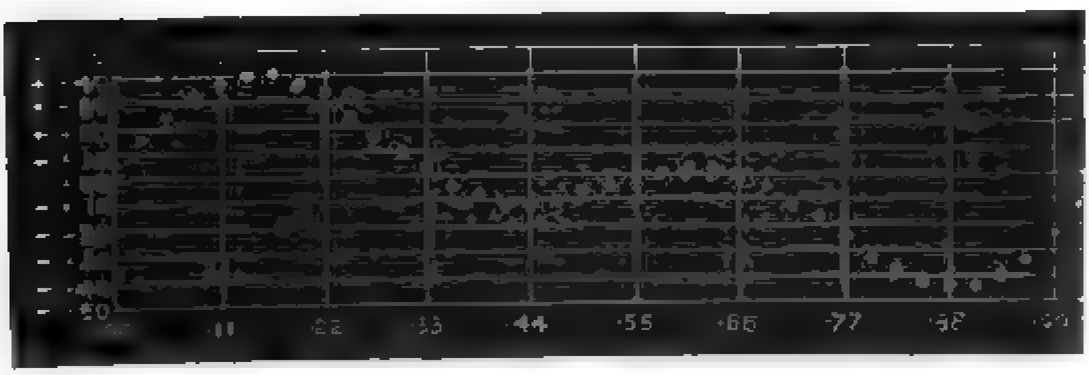
The horizontal scale is fraction of the year.

Fabritius' Correction for Polaris (R.A.) 1894.



The horizontal scale is fraction of the year.

Fabritius' Correction for λ Ursæ Minoris (R.A.) 1894.



The horizontal scale is fraction of the year.

Nautical Almanac Office:
1892 *March* 8.

Results of Double-Star Measures with the 8-inch Equatoreal at Windsor, N. S. Wales, in 1891. By J. Tebbutt.

Ref. No.	Star.	Observed Magnitude.	Approx. Place of Star. R. A.	Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Hour-Angles.		Weight, 1 to 5.
			h m	° ′				″			h m	h m	
1	*p* Eridani	6, 6	1 36	56 45	·739	...	...	7·30	10	170	2 30 E	2 15 E	5
2	„	6, 6	„	„	·745	225·2	10	...	...	300	2 51 E	2 37 E	5
3	„	...	„	„	·750	225·6	10	...	...	300	3 43 E	3 31 E	3
4	„	6, 6	„	„	·758	225·6	10	...	...	...	2 37 E	2 21 E	5
5	„	6, 6	„	„	·758	...	...	7·03	10	...	2 4 E	1 47 E	5
6	„	...	„	„	·805	...	...	7·08	10	170	3 44 E	3 26 E	3
7	„	...	„	„	·991	227·9	10	...	...	230	2 19 W	2 40 W	3
8	„	...	„	„	·991	...	...	7·63	7	170	2 44 W	2 58 W	3
9	Lalande, 4219	8, 8	2 11	18 44	·745	335·6	10	...	..	300	2 32 E	2 20 E	4
10	„	8, 8	„	„	·745	337·2	10	...	...	230	2 20 E	2 5 E	4
11	*α* Centauri	...	14 32	60 23	·515	205·8	10	...	...	300	2 56 E	2 43 E	4
12	„	...	„	„	·559	207·6	10	...	...	230	0 52 W	1 9 W	2
13	„	...	„	„	·561	205·9	10	...	...	230	2 29 E	2 20 E	4
14	„	...	„	„	·561	...	...	19·10	10	170	1 51 E	1 34 E	3
15	„	...	„	„	·583	...	...	19·40	10	170	1 0 E	0 40 E	2
16	„	...	„	„	·583	205·4	10	...	...	300	0 36 E	0 0	3
17	„	...	„	„	·613	205·0	10	...	...	230	0 47 E	0 38 E	3
18	„	...	„	„	·613	...	...	18·91	10	170	0 38 E	0 14 E	3
19	„	...	„	„	·616	...	...	19·09	10	170	0 26 E	0 12 E	3
20	„	...	„	„	·635	207·5	10	...	...	300	4 8 W	4 22 W	3

Ref. No.	Star.	Observed Magnitude.	Approx. Place of Star. R. A.	Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Hour-Angles.		Weight, 1 to 5.
			h m	° ′				″			h m	h m	
21	α Centauri	...	14 32	60 23	·646	206·1	10	...	...	500	3 2 W	3 25 W	4
22	"	...	"	"	·646	...	...	19·85	6	170	3 31 W	3 52 W	3
23	"	...	"	"	·654	...	...	19·41	10	170	1 35 W	2 3 W	2
24	"	...	"	"	·657	...	...	19·43	10	170	1 34 W	1 54 W	3
25	"	...	"	"	·657	...	...	19·61	5	170	2 47 W	2 57 W	4
26	"	...	"	"	·663	...	...	19·23	5	170	1 25 E	1 7 E	3
27	"	...	"	"	·663	...	...	19·24	10	170	0 3 W	0 14 W	4
28	39 Ophiuchi	6, 8	17 11	24 8	·695	...	...	10·57	5	170	3 21 W	3 36 W	...
29	"	...	"	"	·726	...	...	10·53	7	170	2 45 W	2 59 W	...
30	"	...	"	"	·726	354·9	10	...	...	300	3 21 W	3 43 W	...
31	"	...	"	"	·739	353·8	10	...	...	140	2 40 W	2 51 W	5
32	κ Cor. Aust.	6, 7	18 26	38 48	·758	358·3	6	...	...	...	3 29 W	3 39 W	5
33	Brisb. 6556	...	18 54	37 13	·635	277·4	10	...	...	140	0 39 E	0 28 E	5
34	"	...	"	"	·638	280·5	10	...	...	230	1 6 E	0 28 E	4
35	"	7, 7	"	"	·745	...	...	10·15	8	170	2 15 W	2 39 W	5
36	"	7, 7	"	"	·745	280·6	10	...	...	300	3 22 W	3 36 W	5
37	"	...	"	"	·747	281·4	10	...	...	300	1 52 W	2 5 W	5
38	"	...	"	"	·750	280·8	10	...	...	300	1 44 W	1 57 W	3
39	*h* 5075	8, 8	18 54	63 56	·758	110·5	10	...	...	300	3 28 W	3 51 W	4
40	γ Cor. Aust.	...	18 59	37 13	·635	...	...	1·57	10	170	3 7 E	1 52 E	4
41	"	...	"	"	·635	180·1	10	...	...	300	1 36 E	1 17 E	4

Ref. No.	Star.	Observed Magnitude.	Approx. Place of Star. R. A.	Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	M g. Power.	Hour-Angles.		Weight, 1 to 5.
			h m	° ′				″			h m	h m	
42	γ Cor. Aust.	...	18 59	37 13	·638	178·1	10	...	...	300	1 34 E	1 6 E	3
43	„	...	„	„	·643	177·3	10	...	...	300	1 44 E	1 24 E	5
44	„	6, 6	„	„	·739	174·7	10	...	...	300	1 42 W	1 54 W	5
45	„	6, 6	„	„	·739	...	...	1·48	10	170	2 26 W	2 38 W	5
46	„	...	„	„	·742	...	...	1·57	6	170	1 28 W	1 37 W	3
47	„	6, 6	„	„	·745	...	...	1·52	10	170	2 0 W	2 15 W	5
48	„	6, 6	„	„	·745	174·5	10	...	...	300	2 40 W	2 59 W	5
49	„	6, 6	„	„	·745	175·0	10	...	...	300	3 1 W	3 12 W	5
50	„	...	„	„	·747	175·3	10	...	...	300	1 29 W	1 42 W	5
51	„	...	„	„	·750	176·3	10	...	...	300	1 54 W	2 3 W	4
52	„	6, 6	„	„	·758	175·7	10	...	...	...	2 32 W	2 47 W	5

Remarks.

Nos. 1, 2, 4, 5, 6, 9, 10, 21, 22, 26, 27, 31, 33, 34, 39, 40, 43, 44, 45, 46, 47, 48, 49, 50, 52. The line joining the observer's eyes was parallel to that joining the components. Nos. 7, 8, 20, 23, 24, 25, 32, 35, 36, 37, 41, 42. These lines were at right angles.

Nos. 1, 4, 5, 34, 44, 45, 47, 48, 49, 52. Components equal.

Nos. 7, 8. The driving clock acted badly, and the measures were difficult. Nos 9, 10. South component slightly the brighter.

Nos. 11, 13, 14, 15, 16, 17, 18, 19, 26. 27. Observations during sunlight. Nos. 23, 24. Observations in twilight.

No. 28. Large star pale red and companion pale blue.

Nos. 28, 29. Direct distances deduced from observed differences of declination and an assumed position-angle.

No. 33. Components equal and bluish. Nos. 35, 36. The *following* star probably the brighter.

No. 39. The *preceding* component probably the brighter.

Windsor, N. S. Wales :
1892 *January* 22.

Maxima and Minima of Variable Stars Observed during the Years 1889, 1890, *and* 1891. By John Mitchell.

The following results have been derived from observations made with an achromatic of 3·5 inches aperture, using constantly an eyepiece of low power.

The mode of observation has been to compare the variable with stars differing little from it in brightness, and whose magnitudes had been kindly supplied to me by Mr. Baxendell, who, I believe, determined some of them himself, and obtained the remainder from his late father and the late Mr. Pogson.

R *Cygni.*

Maximum: 1889 Oct. 9; mag. 7·1

S *Ursæ Majoris.*

Maximum:	1889 Sept. 15;	mag.	7·6
Minimum:	1890 Jan. 1;	„	12·35
Maximum:	1890 Apr. 18;	„	7·6
Minimum:	1890 Aug. 20;	„	12·25
Minimum:	1891 Apr. 2±;	„	?
Maximum:	1891 July 13:	„	7·75
Minimum:	1891 Nov. 10;	„	12·45

T *Ursæ Majoris.*

Maximum:	1890 June 3;	mag.	7·1
Maximum:	1891 Nov. 1;	„	7·85

Observations have been made as follows:—

	R *Cygni.*	U *Geminorum.*	S *Ursæ Majoris.*	T *Ursæ Majoris.*
In 1889	30 nights.	...	26 nights.	13 nights.
„ 1890	26 „	...	40 „	31 „
„ 1891	30 „	12 nights.	58 „	42 „

Brockholes, Huddersfield:
1892 *February* 25.

Occultation of γ_1 and γ_2 Virginis. By the Rev. A. Freeman.

The disappearances of these stars took place January 19, 1892, a little east of the south point of the bright limb of the Moon. The star γ_1 *Virginis* disappeared at $16^h\ 2^m\ 53^s{\cdot}8$, G.M.T., the star γ_2 at $16^h\ 3^m\ 12^s{\cdot}3$. Dense cloud unfortunately prevented the observation of the reappearances at the dark limb about one hour later. I employed a $6\frac{1}{2}$-inch O.G. with a power of 90. Each star took from 2·5 to 3 seconds, after projection within the limb of the Moon as a bright round point, before it finally disappeared; a separate less bright segment of a star was in each case seen just outside the limb. The times recorded refer to the disappearances of these segments, which were simultaneous with those of the projected stars. I consider that, in this case, the apparent effect of projection was due to the fact that perfect achromatism is impossible with an object-glass composed of two lenses only. The principal rays of light collected by the object-glass in a common focus give the bright star image as seen apparently within the limb, but the apparent diameter of the Moon is enlarged by imperfect achromatism, and the segments of stars are parts of uncorrected images out of focus. The line joining the two stars seemed to the eye inclined about 25° from the normal to the Moon's limb, γ_2 being east of the normal at the disappearance of γ_1. From the Greenwich Ten-Year Catalogue for 1880 I find the mean places of the stars for 1892·0 would be:—

		h	m	s		°	′	″
γ_1 Virg.	R.A.	12	36	11·122,	S.D.	0	51	22·73
γ_2 Virg.	R.A.	12	36	11·296,	S.D.	0	51	28·10

Annual precession, secular variation, and proper motion are the same for both stars. Hence the position angle of γ_2, referred to γ_1, would seem to be 154° 4′·75, and its distance 5″·97. I judged γ_1 to be the brighter of the two stars. The approximate position of my observatory is in lat. 51° 20′ N., long. $3^m\ 0^s$ E.

Murston Rectory, Sittingbourne:
1892 *March* 7.

The Reappearance of Saturn's Rings. By George C. Comstock.

(*Communicated by H. H. Turner, M.A., B.Sc.*)

The communication respecting the reappearance of *Saturn's* rings made to the Royal Astronomical Society by the Rev. A. Freeman, M.A., and published in the *Monthly Notices* for November 1891, makes it proper that I should publish through the same channel the results of observations of *Saturn* made at this observatory, although a brief account of some of them has already appeared in the *Sidereal Messenger* for November.

At my request Mr. S. D. Townley, assistant in the observatory, commenced about the middle of October an examination of *Saturn* on every clear morning, using the Clark equatoreal of 40 cm. aperture with the so-called zone eyepiece, giving a power of 145 diameters. On a few mornings I myself took part in the observations, which is indicated in the following extracts from Mr. Townley's note-book, by the letter *C*, prefixed to those parts of the observing for which I am personally responsible. The remaining, and by far the greater number of, observations are by Mr. Townley. The times are given in mean solar time of the meridian 90° west of Greenwich, and the dates in civil reckoning.

1891 October 16.—Rings not visible. The shadow of the rings on the ball is seen plainly. Also belts on each side and parallel to the shadow; south belt plainer. The shadow of the rings appears to divide the ball into two unequal parts, of which the southern (?) part is the larger. Seeing good. *C.* confirms the above description.

October 20, 4^h 50^m.—Rings not visible, but seeing is not very good. 5^h 24^m. Seeing better than before. Rings visible, but most plainly in preceding limb. *C.* Mr. Townley called me to the telescope, saying that he could see the rings. The ansæ are visible with difficulty, but certainly on both sides of the planet; more plainly on the pr. side. Ansæ project beyond the ball—two-thirds of the diameter of the planet.

At 5^h 45^m made sketch of *Saturn* with power of 310 diameters, with approximate location of the satellites visible near the ball. These were subsequently identified from Marth's ephemeris. At the time of the sketch, Rhea could just be distinguished at its reappearance from behind the ball of the planet. A measurement from the sketch places it $4''\cdot1$ south of the planet's equator at the time of reappearance.

October 22, 4^h 30^m.—Rings not visible. Seeing very bad. 4^h 50^m. Seeing is not much improved. Thought once that I caught a glimpse of the rings on the following side. 5^h 30^m. No rings visible, but daylight too far advanced for the best seeing. *C.* No rings visible at 4^h 45^m and 5^h 55^m.

October 25, 5^h 10^m.—Rings visible by glimpses, extending on both sides of planet to distances of 0·6 or 0·7 of the planet's diameter.

5^h 30^m.—Same as above, with power of 145; but could *not* see rings with power of 310. Images very steady, but faint, on account of heavy fog which envelopes the observatory.

October 26, 5^h 15^m.— Rings visible by glimpses. Seeing so bad that I cannot see the markings on the planet's surface.

October 27, 5^h 15^m.—Same as October 26.

October 31, 5^h 15^m.—Rings plainly visible as continuous lines, extending on each side to a distance of about 0·6 the diameter of the ball. Tried power of 310, but could see nothing. Seeing rather bad. Images diffuse and unsteady.

November 5, 5^h 20^m.—Rings very plainly visible, extending on each side 0·5 the diameter of the ball. Seeing not good.

The above observations, made with superior optical appliances, are entirely inconsistent with Mr. Freeman's conclusion "that the plane of *Saturn's* rings probably passed through the Sun's centre on November 1, at about 6 A.M., or possibly one hour, or two hours at most, earlier"; and it is a matter of surprise that he should not have detected the ansæ on October 30 and 31, since the difference between the apertures of his telescope and the one employed at Madison cannot well explain a difference of ten days in the date of reappearance of the ring.

In one respect, however, I wish to confirm Mr. Freeman's observations. My sketch of October 20, above referred to, shows the broad band across *Saturn's* disc wholly south of the equator, and its southern edge *very slightly curved*, with convexity southwards.

Washburn Observatory:
1892 *January* 1.

Ephemerides of the Satellites of Saturn, 1891–92. By A. Marth. (Concluded.)

The following list of phenomena is a continuation of that published to the end of April, on p. 195. From the middle of April to the end of June the planetocentric latitude of the Earth above the plane of *Saturn's* equator is less than 1°, and the apparent orbits of the satellites are very narrow ellipses, so that the distances of the satellites at the times of their conjunctions are very small. I have therefore considered it worth while to make a search for the conjunctions which occur during the indicated period and are observable in America or Europe, and to insert them in the list, in the hope that favoured observers will duly attend to these rare and interesting test-phenomena, and will measure the differences of the rectangular coordinates parallel to the axes of the planet's disc, or in the position-angles

P and P$\pm 90°$. In order to compress the indications of the conjunctions, the usual sign ☌ has been omitted, the initials of the satellites being placed in line (the quicker-moving first), with the letters *n.* or *s.* (north or south) attached, and followed by the approximate value (expressed in semi-diameters of the planet's equator) of the distance of the satellites from the polar axis of the disc.

As the shadows of Rh., Di., Te. are reported to be discernible, the approximate times of "Sh.," their crossing the central meridian, are inserted. The phenomena for April supplement those already published on p. 194.

G.M.T. 1892.		h	
Apr.	10	13·2	Di. Sh.
		15·9	Te. Sh.
		19·8	Rh. Sh.
	11	8·2	Rh. *s.* Di. *n.* − 6·1
		16·6	En. *s.* Te. *n.* + 1·5
	12	13·2	Te. Sh.
		17·7	Rh. *n.* Titan *s.* − 3·8
		18·5	Te. *s.* Rh. *n.* − 3·4
	13	6·9	Di. Sh.
		9·2	Te. *n.* Di. *s.* − 1·7
		13·3	Di. *s.* En. *n.* − 3·9
	14	10·6	Te. Sh.
		12·7	Te. *s.* Di. *n.* − 1·6
	15	8·2	Rh. Sh.
		15·0	Te. *n.* En. *s.* + 3·7
	16	7·9	Te. Sh.
		10·8	Te. *s.* En. *n.* − 2·1
	18	18·3	Di. Sh.
	19	11·1	Rh. *s.* Te. *n.* + 4·3
		12·9	Rh. *s.* En. *n.* + 3·5
		20·7	Rh. Sh.
	20	8·9	Te. *s.* En. *n.* − 4·0
		20·2	En. *n.* Titan *n.* + 2·7
	21	12·0	Di. Sh.
	22	10·0	Rh. *n.* En. *s.* + 4·0
		10·9	Di. *n.* Te. − 5·0
	23	15·4	Te. *s.* En. *n.* + 3·4
		21·1	Te. Sh.
	24	9·1	Rh. Sh.
		12·0	Di. *s.* En. *n.* − 3·9
		14·4	Rh. *s.* En. *n.* − 3·1
		14·5	Rh. *s.* Te. *n.* − 3·2
		14–16·6	En. closely pursued but not overtaken by Te.
	25	16·2	Di. Ecl. R.
		16·2	Te. *s.* Di. *n.* + 1·3
		18·4	Te. Sh.
	26	13·4	Di. Sh.
	27	15·8	Te. Sh.
	28	10·7	Te. *n.* Titan *s.* − 2·2
		13·7	Di. *n.* Rh. *s.* + 3·5
		15·3	Titan *s.* En. *n.* − 3·8
		21·6	Rh. Sh.
	29	13·1	Te. Sh.
		17·1	Di. Sh.

G.M.T. 1892.		h	
May	1	7·3	Rh. ε
		8·5	Te. β
		10·4	Te. Sh.
		11·4	Te. γ
		12·2	En. θ
		12·4	Mi. ε
		12·8	En. *n.* Te. *s.* − 1·9
		13·4	Te. η
		16·3	Rh. *n.* Di. *n.* + 6·3
		17·1	Mi. ζ
		18·6	En. ε
	2	8·5	Di. β
		10·5	Te. Ecl. R.
		10·8	Di. Sh.
		11·0	En. η
		11·0	Mi. ε
		11·8	Di. γ
		12·1	Te. ε
		14·0	Di. η
		16·4	Mi. ζ
	3	7·0	Rh. β
		7·7	Te. Sh.
		8·7	Te. γ
		9·6	Mi. ε
		10·1	Rh. Sh.
		10·7	Te. η
		10·9	Rh. γ
		12·9	Te. *s.* Di. *n.* − 3·5
		13·5	Rh. η
		13·6	En. ζ
		15·0	Mi. ζ
		15·1	Di. θ
		17·4	Di. δ
	4	7·9	Te. Ecl. R.
		8·3	Mi. ε
		9·4	Te. ε
		12·4	En. ε
		13·7	Mi. ζ
	5	7·7	Di. η
		8·0	Te. η
		9·1	Di. *s.* Rh. *n.* − 3·1
		9·2	Te. *s.* Rh. *n.* − 3·0
		10·7	Rh. θ
		10·8	Di. *s.* En. *n.* − 4·0
		11·1	Te. *s.* En. *n.* − 3·9

G.M.T. 1892.		h	
May	5	12·3	Mi. ζ
		13·2	Rh. δ
		14·9	En. θ
		18·1	Rh. Ecl. R.
		18·2	Mi. η
		19·7	Rh. ϵ
	6	7·3	Titan δ
		7·3	En. ζ
		8·8	Di. θ
		10·9	Mi. ζ
		11·0	Di. δ
		13·2	Titan α
		13·7	En. η
		15·0	Di. Ecl. R.
		15·7	Di. *n.* Titan *n.* + 1·9
		16·5	Di. ϵ
		16·8	Mi. η
		17·1	Titan ϵ
	7	8·9	Rh. *s.* Di. *s.* + 6·0
		9·5	Mi. ζ
		15·4	Mi. η
		16·2	En. ζ
		16·8	Rh. ζ
		17·7	Di. ζ
	8	8·1	Mi. ζ
		8·7	En. θ
		9·8	Rh. *s.* Di. *s.* − 5·9
		14·0	Mi. η
		15·0	En. ϵ
	9	8·7	Di. Ecl. R.
		10·2	Di. ϵ
		12·7	Mi. η
		17·6	En. θ
		18·1	Mi. θ
		18·4	Te. θ
	10	8·0	Rh. ϵ
		9·1	En. *s.* Rh. *n.* + 2·8
		9·8	Di. *s.* Rh. *n.* + 3·2
		10·0	En. ζ
		11·3	Mi. η
		11·3	Di. ζ
		12·5	Rh. *n.* Te. *s.* + 4·5
		13·5	Di. β
		16·0	Di. Sh.
		16·3	En. η
		16·7	Mi. θ
		16·8	Di. γ
		17·1	Te. ζ
	11	8·8	En. ϵ
		9·9	Mi. η
		15·3	Mi. θ
		15·7	Te. θ
		17·7	Te. δ
	12	8·5	Mi. η
		11·0	Rh. Sh.
		11·3	En. θ
		11·7	Rh. γ
		12·6	En. *n.* Rh. *s.* − 1·5
		13·9	Mi. θ

G.M.T. 1892.		h	
May	12	14·2	Rh. η
		14·4	Te. ζ
		16·4	Te. β
		17·7	En. ϵ
		18·3	Te. Sh.
	13	9·6	Di. Sh.
		10·1	En. η
		10·5	Di. γ
		11·6	Te. *n.* En. *s.* − 3·1
		12·5	Mi. θ
		12·7	Di. η
		12·9	Te. *n.* Di. *s.* − 2·4
		13·0	Te. θ
		15·0	Te. δ
		15·9	Di. *s.* En. *n.* − 4·0
		18·4	Te. Ecl. R.
		18·4	Mi. ϵ
		19·8	Titan ζ
		19·9	Te. *n.* Titan *s.* + 2·3
		19·9	Te. ϵ
	14	9·3	Titan η
		10·6	Rh. *n.* Titan *s.* − 2·7
		11·1	Mi. θ
		11·4	Rh. θ
		11·7	Te. ζ
		12·1	Di. *n.* Titan *s.* − 3·3
		12·7	En. ζ
		13·7	Te. β
		13·9	Di. θ
		14·0	Rh. δ
		15·6	Te. Sh.
		16·1	Di. δ
		16·6	Te. γ
		17·1	Mi. ϵ
		18·6	Te. η
		19·0	Rh. Ecl. R.
		19·0	En. η
	15	9·8	Mi. θ
		10·3	Te. θ
		11·4	En. ϵ
		12·3	Te. δ
		15·7	Mi. ϵ
		15·8	Te. Ecl. R.
		17·2	Te. ϵ
	16	9·0	Te. ζ
		9·6	Di. *s.* En. *n.* − 4·0
		11·0	Te. β
		12·9	Te. Sh.
		13·9	Te. γ
		14·0	En. θ
		14·3	Mi. ϵ
		14·9	Te. *s.* En. *n.* − 1·7
		15·9	Te. η
		17·6	Rh. ζ
	17	8·5	Te. *n.* En. *n.* − 1·7
		9·6	Te. δ
		9·8	Di. δ
		12·8	En. η
		12·9	Mi. ϵ

G.M.T. 1892.	h	
May 17	13·1	Te. Ecl. R.
	13·8	Di. Ecl. R.
	14·5	Te. ϵ
	15·2	Di. ϵ
18	8·3	Te. β
	10·2	Te. Sh.
	11·2	Te. γ
	11·5	Mi. ϵ
	13·2	Te. η
	15·3	En. ζ
	16·4	Di. ζ
	16·9	Mi. ζ
	18·6	Di. β
19	8·8	Rh. ϵ
	10·1	Mi. ϵ
	10·4	Te. Ecl. R.
	11·8	Te. ϵ
	14·1	En. ϵ
	15·5	Mi. ζ
20	7·5	Te. Sh.
	8·5	Te. γ
	8·8	Mi. ϵ
	8·9	Di. ϵ
	10·5	Te. η
	13·3	Te. *s*. En. *n*. − 3·8
	14·2	Mi. ζ
	16·6	En. θ
21	8·6	Rh. β
	9·1	En. ζ
	9·1	Te. ϵ
	10·0	Di. ζ
	11·9	Rh. Sh.
	12·3	Di. β
	12·5	Rh. γ
	12·8	Mi. ζ
	14·7	Di. Sh.
	15·1	Rh. η
	15·4	En. η
	15·6	Di. γ
	17·8	Di. η
22	11·4	Mi. ζ
	11·6	Titan α
	13·8	Di. *n*. Te. *s*. − 4·8
	15·5	Titan ϵ
	17·1	En. *s*. Titan *n*. + 2·8
	17·3	Mi. η
	18·0	En. ζ
	18·9	Di. θ
23	10·0	Mi. ζ
	10·4	En. θ
	12·3	Rh. θ
	14·8	Rh. δ
	15·9	Mi. η
	16·8	En. ϵ
24	8·3	Di. Sh.
	8·6	Mi. ζ
	9·2	En. η
	9·3	Di. γ
	11·5	Di. η

G.M.T. 1892.	h	
May 24	14·6	Mi. η
	14·7	Di. *s*. En. *n*. − 4·0
	16·0	Di. *s*. Te. *n*. − 4·6
25	11·7	En. ζ
	12·6	Di. θ
	12·9	Rh. *n*. Te. *n*. + 4·9
	13·2	Mi. γ
	14·2	Di. δ
	18·1	En. η
	18·5	Rh. ζ
	18·6	Mi. θ
	18·9	Di. Ecl. R.
26	9·1	Rh. *s*. Te. *s*. − 4·9
	10·5	En. ϵ
	11·8	Mi. η
	17·2	Mi. θ
	18·2	Te. θ
27	8·4	Di. *s*. En. *n*. − 4·0
	10·4	Mi. η
	13·1	En. θ
	15·7	Rh. *n*. Di. *s*. − 6·3
	15·8	Mi. θ
	16·8	Te. ζ
28	8·4	Rh. Ecl. R.
	8·5	Di. δ
	9·0	Mi. η
	9·7	Rh. ϵ
	11·9	En. η
	12·6	Di. Ecl. R.
	13·7	Te. *n*. En. *s*. − 3·3
	14·0	Di. ϵ
	14·4	Mi. θ
	15·5	Te. θ
	17·5	Te. δ
29	11·7	Te. *s*. En. *s*. + 3·6
	13·1	Mi. θ
	14·1	Te. ζ
	14·4	En. ζ
	15·1	Di. ζ
	16·1	Te. β
	17·4	Di. β
	18·1	Te. Sh.
	18·4	Titan ζ
30	7·9	Titan η
	9·5	Rh. β
	11·0	Te. *n*. Titan *s*. − 3·3
	11·7	Mi. θ
	12·8	Te. θ
	12·8	Rh. Sh.
	13·2	En. ϵ
	13·4	Rh. γ
	14·8	Te. δ
	15·9	Rh. η
31	7·7	Di. ϵ
	9·6	Di. *n*. Te. *s*. + 3·4
	10·3	Mi. θ
	11·5	Te. ζ
	13·5	Te. β
	15·4	Te. Sh.

G.M.T. 1892	h	
May 31	15·7	En. θ
	16·2	Mi. ϵ
	16·4	Te. γ
June 1	8·2	En. ζ
	8·8	Di. ζ
	8·9	Mi. θ
	10·1	Te. θ
	11·1	Di. β
	12·1	Te. δ
	13·1	Rh. θ
	13·5	Di. Sh.
	13·9	En. *s*. Rh. *n*. − 1·9
	14·3	Di. γ
	14·5	En. η
	14·8	Mi. ϵ
	15·6	Te. Ecl. R.
	15·7	Rh. δ
	16·5	Di. η
	17·0	Te. ϵ
2	8·8	Te. ζ
	10·8	Te. β
	12·8	Te. Sh.
	13·4	Mi. ϵ
	13·7	Te. γ
	15·7	Te. η
	17·1	En. θ
	17·7	Di. θ
3	7·4	Te. θ
	9·4	Te. δ
	9·5	En. θ
	10·8	Rh. *s*. Di. *n*. + 6·1
	12·1	Mi. ϵ
	12·9	Te. Ecl. R.
	14·3	Te. ϵ
	15·9	En. ϵ
4	8·0	Di. γ
	8·1	Te. β
	8·3	En. η
	10·1	Te. Sh.
	10·2	Di. η
	10·8	Mi. ϵ
	11·0	Te. γ
	13·0	Te. η
	13·0	Di. *s*. En. *s*. − 4·0
	16·1	Mi. ζ
5	9·3	Mi. ϵ
	10·2	Te. Ecl. R.
	10·9	En. ζ
	11·2	Te. *n*. En. *s*. + 2·2
	11·4	Di. θ
	11·6	Te. ϵ
	13·6	Di. δ
	14·7	Mi. ζ
	17·2	En. η
	17·7	Di. Ecl. R.
6	8·3	Te. γ
	9·3	Rh. Ecl. R.
	9·6	En. ϵ
	10·3	Te. η

G.M.T. 1892	h	
June 6	10·6	Rh. ϵ
	13·3	Mi. ζ
	14·1	Rh. *n*. En. *n*. + 4·0
	15·6	Rh. *n*. Di. *s*. + 4·7
	16·8	Titan *n*. Te. *s*. − 4·9
7	9·0	Te. ϵ
	10·5	Titan α
	11·9	Mi. ζ
	12·2	En. θ
	14·4	Titan ϵ
8	7·3	Di. δ
	7·6	Te. η
	7·8	Rh. ζ
	10·4	Rh. β
	10·6	Mi. ζ
	11·0	En. η
	11·4	Di. Ecl. R.
	12·8	Di. ϵ
	13·8	Rh. Sh.
	14·3	Rh. γ
	16·5	Mi. η
	16·8	Rh. η
9	9·2	Mi. ζ
	9·4	Te. *n*. En. *s*. + 4·0
	10·2	Di. *s*. Te. *n*. + 4·3
	13·5	En. ζ
	13·9	Di. ζ
	15·1	Mi. η
	16·2	Di. β
10	9·5	Rh. *n*. Te. *s*. − 4·5
	12·3	En. ϵ
	13·7	Mi. η
	14·0	Rh. θ
	16·6	Rh. δ
11	12·0	Di. *n*. Te. *s*. + 5·0
	12·3	Mi. η
	14·9	En. θ
12	9·9	Di. β
	11·0	Mi. η
	12·3	Di. Sh.
	13·1	Di. γ
	13·7	En. η
	15·3	Di. η
13	9·6	Mi. η
	11·0	Rh. *s*. Di. *n*. − 5·0
	15·0	Mi. θ
	16·2	En. ζ
	16·5	Di. θ
	16·7	Te. ζ
14	7·5	Titan *s*. Di. *n*. + 5·6
	8·2	Mi. η
	8·7	En. θ
	13·6	Mi. θ
	15·0	En. ϵ
	15·3	Te. θ
	15·9	En. *n*. Titan *s*. + 2·8
	17·3	Te. δ
	17·4	Titan ζ
15	8·1	En. *s*. Titan *s*. − 2·7

G.M.T. 1892.	h	
June 15	9·1	Di. η
	10·2	Rh. Ecl. R.
	11·5	Rh. ϵ
	12·1	Titan *s*. En. *s*. −4·0
	12·2	Mi. θ
	12·3	Di. *s*. En. *s*. −4·0
	12·9	Te. *s*. Rh. *n*. +3·0
	13·0	Di. *s*. Titan *s*. −4·3
	14·0	Te. ζ
	16·0	Te. β
16	10·0	En. ζ
	10·2	Di. θ
	10·9	Mi. θ
	12·4	Di. δ
	12·6	Te. θ
	14·6	Te. δ
17	8·8	Rh. ζ } ☌ +2·3
	8·8	En. ϵ }
	9·5	Mi. θ
	10·1	Te. *s*. En. *n*. +3·0
	11·3	Te. ζ
	11·3	Rh. β
	13·3	Te. β
	14·7	Rh. Sh.
	15·2	Rh. γ
	15·3	Te. Sh.
	15·4	Mi. ϵ
	16·2	Te. γ
18	10·0	Te. θ
	11·3	En. θ
	12·0	Te. δ
	14·0	Mi. ϵ
	15·5	Te. Ecl. R.
	16·9	Te. ϵ
19	8·6	Te. ζ
	10·1	En. η
	10·2	Di. Ecl. R.
	10·6	Te. β
	11·6	Di. ϵ
	12·5	En. *s*. Rh. *n*. −3·5
	12·6	Te. Sh.
	13·5	Te. γ
	15·0	Rh. θ
	15·5	Te. η
20	9·3	Te δ
	10·5—13	En. closely followed but not overtaken by Di.
	11·3	Mi. ϵ
	12·7	En. ζ
	12·8	Di. ζ
	12·8	Te. Ecl. R.
	13·4	En. *s*. Te. *n*. +1·8
	13·5	Te. *n*. Di. *s*. +1·9
	14·2	Te. ϵ
	15·0	Di. β
21	9·9	Mi. ϵ
	10·0	Te. Sh.
	10·8	Te. γ
	11·5	En. ϵ
	12·8	Te. η
June 21	15·3	Mi. ζ
22	10·1	Te. Ecl. R.
	11·5	Te. ϵ
	13·7	Rh. *s*. Titan *n*. −5·7
	14·0	En. θ
23	8·2	Te. γ
	8·7	Di. β
	9·7	Titan α
	10·2	Te. η
	11·2	Di. Sh.
	12·0	Di. γ
	12·5	Mi. ζ
	12·8	En. η
	13·6	Titan ϵ
	14·2	Di. η
24	8·8	Te. ϵ
	11·1	Rh. Ecl. R.
	11·1	Mi. ζ
	12·5	Rh. ϵ
	14·0	En. *s*. Rh. *n*. +3·1
	15·3	Di. θ
	15·4	En. ζ
25	9·8	Mi. ζ
	14·1	En. ϵ
26	7·9	Di. η
	8·4	Mi. ζ
	9·7	Rh. ζ
	11·1	Di. *s*. En. *n*. −4·0
	12·3	Rh. β
	14·3	Mi. η
	15·7	Rh. Sh.
	16·2	Rh. γ
27	9·1	Di. θ
	9·1	En. ζ
	11·3	Di. δ
	12·9	Mi. η
	15·3	Di. Ecl. R.
	15·5	En. η
	16·8	Di. ϵ
28	11·5	Mi. η
	12·6	Di. *s*. Te. *s* +4·9
	15·7	Di. *s*. En. *s* +3·4
	16·0	Rh. θ
29	10·2	Mi. η
	10·5	En. θ
	15·6	Mi. θ
	16·8	En. ϵ
30	9·0	Di. Ecl. R.
	9·3	En. η
	9·5	Di. ϵ
	12·9	Di. *n*. Titan *s*. +3·6
	14·2	Mi. θ
	16·2	Te. *s*. Titan *s*. +2·5
	16·2	Rh. *s*. Di. *n*. +5·1
	16·6	Te. ζ
	16·8	Titan ζ
July 1	9·0	Rh. *s*. Titan *s*. −3·2
	9·3	Di. *n*. En. *n*. +3·6
	11·3	Rh. *s*. Te. *n*. −4·3
	11·6	Di. ζ

G.M.T. 1892.	h	
July 1	11·7	Te. n. Titan s. −4·1
	11·8	En. ζ
	12·8	Mi. θ
	13·8	Di. β
	15·2	Te. θ
	16·3	Di. Sh.
2	13·9	Te. ζ
	15·9	Te. β
3	12·0	Rh. Ecl. R.
	12·5	Te. θ
	13·5	Rh. ε
	14·5	Te. δ
4	7·6	Di. β
	10·8	Di. γ
	11·2	Te. ζ
	13·0	Di. η
	13·2	Te. β
5	9·9	Te. θ
	10·7	Rh. ζ
	11·9	Te. δ
	13·3	Rh. β
	14·2	Di. θ
	15·3	Te. Ecl. R.
6	8·5	Te. ζ
	10·5	Te. β
	13·4	Te. γ
	15·4	Te. η
7	9·2	Te. δ
	12·6	Te. Ecl. R.
	14·1	Te. ε
	17·0	Rh. θ
8	7·9	Te. β
	7·9	Di. θ
	10·1	Di. δ
	10·8	Te. γ
	12·8	Te. η

G.M.T. 1892.	h	
July 8	14·1	Di. Ecl. R.
	15·6	Di. ε
9	9·3	Titan α
	10·0	Te. Ecl. R.
	11·4	Te. ε
	13·2	Titan ε
10	8·1	Te. γ
	8·2	Rh. η
	10·1	Te. η
11	7·3	Te. Ecl. R.
	7·8	Di. Ecl. R.
	8·7	Te. ε
	9·4	Di. ε
12	7·4	Te. η
	8·0	Rh. δ
	10·5	Di. ζ
	12·7	Di. β
	12·9	Rh. Ecl. R.
	14·5	Rh. ε
14	11·7	Rh. ζ
	14·3	Rh. β
15	9·7	Di. γ
	11·9	Di. η
16	13·1	Di. θ
	15·3	Di. δ
	16·6	Titan ζ
17	6·1	Titan η
19	9·3	Rh. η
21	9·1	Rh. δ
	13·8	Rh. Ecl. R.
	15·5	Rh. ε
23	12·8	Rh. ζ
	14·4	Rh. β
25	9·3	Titan α
	13·1	Titan ε

Ephemeris for Physical Observations of Mars, 1892. By A. Marth.

Greenwich Noon.	Angle of Position of ♂'s Axis.	Areographical Long.	Areographical Lat. of Centre of Disc.	Apparent Diameter.	q	Q	E	Light-ratio.
1892.	°	°	°	″	″	°	°	
May 1	11·13	78·92	−12·52	10·80	1·34	259·00	41·27	0·339
3	10·51	59·76	12·82	11·01	1·36	258·67	41·16	0·353
5	9·90	40·61	13·12	11·22	1·38	258·35	41·04	0·369
7	9·29	21·47	13·41	11·44	1·40	258·05	40·90	0·385
9	8·69	2·33	13·68	11·66	1·41	257·76	40·74	0·402
11	8·10	343·21	13·94	11·89	1·43	257·48	40·56	0·420
13	7·51	324·11	14·18	12·13	1·44	257·22	40·36	0·439
15	6·93	305·02	14·42	12·37	1·46	256·98	40·14	0·459
17	6·36	285·94	14·64	12·62	1·47	256·75	39·90	0·480
19	5·81	266·88	−14·85	12·88	1·48	256·54	39·63	0·502

Greenwich Noon.	Angle of Position of ♂'s Axis.	Areographical Long.	Lat. of Centre of Disc.	Apparent Diameter.	q	Q	E	Light-ratio.
1892.	°	°	°	″	″	°	°	
May 21	5·26	247·83	−15·04	13·15	1·49	256·35	39·34	0·526
23	4·73	228·80	15·22	13·42	1·50	256·17	39·02	0·551
25	4·21	209·80	15·39	13·70	1·50	256·02	38·67	0·577
27	3·70	190·81	15·54	13·99	1·51	255·88	38·30	0·605
29	3·21	171·85	15·68	14·28	1·51	255·77	37·90	0·634
31	2·74	152·91	−15·80	14·59	1·50	255·68	37·47	0·665
June 2	2·28	134·00	15·91	14·90	1·50	255·61	37·00	0·698
4	1·84	115·12	16·01	15·22	1·49	255·56	36·50	0·733
6	1·42	96·26	16·09	15·55	1·48	255·54	35·97	0·769
8	1·02	77·44	16·15	15·88	1·47	255·55	35·41	0·808
10	0·64	58·64	−16·20	16·22	1·45	255·59	34·81	0·848
12	0·28	39·88	16·24	16·57	1·43	255·66	33·17	0·891
14	359·94	21·16	16·26	16·93	1·40	255·76	33·49	0·936
16	359·63	2·47	16·26	17·29	1·37	255·90	32·77	0·983
18	359·34	343·82	16·25	17·66	1·34	256·07	32·01	1·032
20	359·08	325·21	−16·22	18·04	1·30	256·29	31·20	1·084
22	358·84	306·64	16·18	18·42	1·26	256·55	30·34	1·138
24	358·64	288·12	16·12	18·80	1·21	256·86	29·44	1·194
26	358·46	269·65	16·05	19·19	1·16	257·23	28·49	1·253
28	358·32	251·22	15·96	19·58	1·11	257·66	27·50	1·313
30	358·20	232·84	−15·86	19·97	1·05	258·16	26·45	1·376
July 2	358·11	214·51	15·75	20·36	0·98	258·74	25·35	1·440
4	358·06	196·23	15·62	20·75	0·91	259·41	24·21	1·505
6	358·04	178·00	15·48	21·13	0·84	260·18	23·02	1·572
8	358·05	159·82	15·33	21·51	0·77	261·08	21·77	1·639
10	358·09	141·68	−15·16	21·88	0·69	262·12	20·48	1·707
12	358·16	123·60	14·99	22·24	0·62	263·34	19·15	1·775
14	358·26	105·57	14·81	22·58	0·54	264·77	17·78	1·841
16	358·40	87·58	14·61	22·91	0·46	266·47	16·37	1·906
18	358·57	69·64	14·41	23·22	0·39	268·53	14·92	1·969
20	358·76	51·74	−14·21	23·51	0·32	271·06	13·45	2·029
22	358·98	33·88	14·00	23·78	0·26	274·23	11·97	2·085
24	359·23	16·06	13·79	24·02	0·20	278·31	10·49	2·137
26	359·50	358·28	13·58	24·23	0·15	283·72	9·04	2·183
28	359·79	340·52	13·37	24·41	0·11	291·1	7·66	2·223
30	0·10	322·78	−13·16	24·55	0·08	301·5	6·44	2·256
Aug. 1	0·41	305·05	12·96	24·66	0·06	316·1	5·48	2·282
3	0·74	287·34	−12·77	24·74	0·05	335·1	4·98	2·300

Greenwich Noon.	Angle of Position of ♂'s Axis.	Areographical Long. of Centre of Disc.	Lat.	Apparent Diameter.	q	Q	E	Light-ratio.
1892.	°	°	°	"	"	°	°	
Aug. 5	1·07	269·64	−12·58	24·78	0·05	355·7	5·07	2·310
7	1·40	251·93	12·41	24·78	0·06	13·6	5·74	2·312
9	1·73	234·22	−12·25	24·74	0·09	26·9	6·88	2·306
11	2·05	216·50	12·11	24·67	0·12	36·3	8·10	2·292
13	2·36	198·76	11·98	24·57	0·17	43·13	9·53	2·271
15	2·66	181·00	11·87	24·43	0·23	48·15	11·02	2·242
17	2·95	163·21	11·79	24·26	0·29	52·00	12·54	2·207
19	3·21	145·39	−11·72	24·06	0·36	55·04	14·06	2·166
21	3·45	127·54	11·67	23·83	0·44	57·49	15·58	2·119
23	3·67	109·65	11·65	23·57	0·52	59·51	17·07	2·067
25	3·86	91·71	11·65	23·29	0·60	61·21	18·53	2·012
27	4·02	73·73	11·67	23·00	0·69	62·66	19·95	1·954
29	4·14	55·70	−11·72	22·68	0·78	63·89	21·33	1·893
31	4·23	37·62	11·79	22·35	0·87	64·95	22·66	1·831
Sept. 2	4·29	19·49	11·88	22·01	0·95	65·87	23·95	1·768
4	4·32	1·31	11·99	21·66	1·03	66·67	25·19	1·704
6	4·31	343·08	12·13	21·30	1·11	67·37	26·38	1·640
8	4·27	324·80	−12·29	20·94	1·19	67·98	27·52	1·577
10	4·20	306·46	12·46	20·57	1·26	68·51	28·61	1·515
12	4·10	288·07	12·66	20·20	1·32	68·97	29·65	1·454
14	3·96	269·64	12·87	19·83	1·38	69·36	30·64	1·394
16	3·80	251·15	13·10	19·45	1·44	69·70	31·58	1·336
18	3·60	232·62	−13·35	19·08	1·49	69·98	32·48	1·279
20	3·37	214·04	13·61	18·72	1·54	70·22	33·33	1·244
22	3·11	195·41	13·88	18·36	1·58	70·41	34·14	1·172
24	2·83	176·74	14·17	18·00	1·62	70·57	34·90	1·121
26	2·52	158·02	14·47	17·64	1·65	70·69	35·61	1·072
28	2·18	139·26	−14·78	17·29	1·68	70·77	36·28	1·026
30	1·81	120·45	15·10	16·95	1·70	70·83	36·92	0·981
Oct. 2	1·42	101·60	15·43	16·62	1·72	70·86	37·52	0·938
4	1·01	82·72	15·76	16·29	1·73	70·87	38·08	0·898
6	0·58	63·80	16·10	15·97	1·74	70·85	38·60	0·859
8	0·13	44·84	−16·45	15·65	1·75	70·82	39·09	0·822
10	359·66	25·85	16·80	15·34	1·76	70·77	39·55	0·787
12	359·16	6·83	17·15	15·04	1·76	70·70	39·98	0·753
14	358·65	347·77	17·51	14·75	1·76	70·61	40·38	0·721
16	358·12	328·68	17·87	14·46	1·75	70·52	40·75	0·690
18	357·58	309·55	−18·23	14·18	1·75	70·41	41·09	0·661

Greenwich Noon.	Angle of Position of ♂'s Axis.	Areographical Long.	Lat. of Centre of Disc.	Apparent Diameter.	q	Q	E	Light-ratio.
1892.	°	°	°	"	"	°	°	
Oct. 20	357·02	290·40	−18·58	13·91	1·74	70·29	41·41	0·634
22	356·45	271·22	18·94	13·64	1·73	70·16	41·70	0·607
24	355·86	252·01	19·30	13·38	1·72	70·03	41·96	0·582
26	355·25	232·77	19·65	13·13	1·70	69·89	42·20	0·558
28	354·64	213·50	−20·00	12·88	1·69	69·75	42·42	0·536
30	354·01	194·21	20·34	12·64	1·67	69·60	42·62	0·515
Nov. 1	353·38	174·90	20·68	12·41	1·65	69·45	42·80	0·494
3	352·73	155·56	21·02	12·18	1·63	69·30	42·96	0·475
5	352·07	136·20	21·35	11·96	1·61	69·15	43·10	0·456
7	351·40	106·82	−21·67	11·74	1·59	68·99	43·22	0·438
9	350·73	97·41	21·98	11·53	1·57	68·84	43·32	0·421
11	350·05	77·98	22·28	11·33	1·55	68·69	43·41	0·405
13	349·37	58·54	22·58	11·13	1·53	68·54	43·48	0·390
15	348·68	39·08	22·87	10·93	1·50	68·39	43·54	0·375
17	347·98	19·60	−23·14	10·74	1·48	68·24	43·58	0·361
19	347·28	0·10	23·41	10·56	1·46	68·10	43·61	0·348
21	346·57	340·58	23·67	10·38	1·43	67·96	43·63	0·335
23	345·86	321·05	23·91	10·20	1·41	67·82	43·63	0·323
25	345·15	301·50	24·14	10·03	1·38	67·70	43·61	0·312
27	344·44	281·94	−24·36	9·86	1·36	67·58	43·59	0·301
29	343·72	262·36	24·57	9·70	1·34	67·46	43·55	0·290
Dec. 1	343·00	242·77	24·76	9·54	1·31	67·35	43·51	0·280
3	342·29	223·16	24·94	9·39	1·29	67·24	43·45	0·270
5	341·58	203·54	25·11	9·24	1·26	67·14	43·38	0·261
7	340·87	183·92	−25·26	9·10	1·24	67·05	43·30	0·252
9	340·16	164·28	25·40	8·95	1·21	66·97	43·21	0·244
11	339·46	144·64	25·53	8·81	1·19	66·89	43·12	0·236
13	338·76	124·98	25·64	8·68	1·17	66·82	43·02	0·228
15	338·07	105·32	25·73	8·55	1·14	66·76	42·90	0·221
17	337·38	85·65	−25·81	8·42	1·12	66·71	42·78	0·214
19	336·70	65·97	25·87	8·29	1·10	66·66	42·65	0·207
21	336·03	46·28	25·92	8·17	1·07	66·63	42·51	0·200
23	335·36	26·59	25·95	8·05	1·05	66·60	42·36	0·194
25	334·70	6·90	25·96	7·93	1·03	66·59	42·21	0·188
27	334·05	347·20	−25·96	7·82	1·01	66·58	42·05	0·182
29	333·42	327·50	25·94	7·71	0·98	66·58	41·88	0·177
31	333·79	307·79	−25·91	7·60	0·96	66·59	41·70	0·172

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1892.	°	°	°	"	"	°	°	
Aug. 5	1·07	269·64	−12·58	24·78	0·05	355·7	5·07	2·310
7	1·40	251·93	12·41	24·78	0·06	13·6	5·74	2·312
9	1·73	234·22	−12·25	24·74	0·09	26·9	6·88	2·306
11	2·05	216·50	12·11	24·67	0·12	36·3	8·10	2·292
13	2·36	198·76	11·98	24·57	0·17	43·13	9·53	2·271
15	2·66	181·00	11·87	24·43	0·23	48·15	11·02	2·242
17	2·95	163·21	11·79	24·26	0·29	52·00	12·54	2·207
19	3·21	145·39	−11·72	24·06	0·36	55·04	14·06	2·166
21	3·45	127·54	11·67	23·83	0·44	57·49	15·58	2·119
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27	4·02	73·73	11·67	23·00	0·69	62·66	19·95	1·954
29	4·14	55·70	−11·72	22·68	0·78	63·89	21·33	1·893
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6	4·31	343·08	12·13	21·30	1·11	67·37	26·38	1·640
8	4·27	324·80	−12·29	20·94	1·19	67·98	27·52	1·577
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12	4·10	288·07	12·66	20·20	1·32	68·97	29·65	1·454
14	3·96	269·64	12·87	19·83	1·38	69·36	30·64	1·394
16	3·80	251·15	13·10	19·45	1·44	69·70	31·58	1·336
18	3·60	232·62	−13·35	19·08	1·49	69·98	32·48	1·279
20	3·37	214·04	13·61	18·72	1·54	70·22	33·33	1·244
22	3·11	195·41	13·88	18·36	1·58	70·41	34·14	1·172
24	2·83	176·74	14·17	18·00	1·62	70·57	34·90	1·121
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28	2·18	139·26	−14·78	17·29	1 68	70·77	36·28	1·026
30	1·81	120·45	15·10	16·95	1·70	70·83	36·92	0·981
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6	0·58	63·80	16·10	15·97	1·74	70·85	38·60	0·859
8	0·13	44·84	−16·45	15·65	1·75	70·82	39·09	0·822
10	359·66	25·85	16·80	15·34	1·76	70·77	39·55	0·787
12	359·16	6·83	17·15	15·04	1·76	70·70	39·98	0·753
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16	358·12	328·68	17·87	14·46	1·75	70·52	40·75	0·690
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22	356·45	271·22	18·94	13·64	1·73	70·16	41·70	0·607
24	355·86	252·01	19·30	13·38	1·72	70·03	41·96	0·582
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28	354·64	213·50	−20·00	12·88	1·69	69·75	42·42	0·536
30	354·01	194·21	20·34	12·64	1·67	69·60	42·62	0·515
Nov. 1	353·38	174·90	20·68	12·41	1·65	69·45	42·80	0·494
3	352·73	155·56	21·02	12·18	1·63	69·30	42·96	0·475
5	352·07	136·20	21·35	11·96	1·61	69·15	43·10	0·456
7	351·40	106·82	−21·67	11·74	1·59	68·99	43·22	0·438
9	350·73	97·41	21·98	11·53	1·57	68·84	43·32	0·421
11	350·05	77·98	22·28	11·33	1·55	68·69	43·41	0·405
13	349·37	58·54	22·58	11·13	1·53	68·54	43·48	0·390
15	348·68	39·08	22·87	10·93	1·50	68·39	43·54	0·375
17	347·98	19·60	−23·14	10·74	1·48	68·24	43·58	0·361
19	347·28	0·10	23·41	10·56	1·46	68·10	43·61	0·348
21	346·57	340·58	23·67	10·38	1·43	67·96	43·63	0·335
23	345·86	321·05	23·91	10·20	1·41	67·82	43·63	0·323
25	345·15	301·50	24·14	10·03	1·38	67·70	43·61	0·312
27	344·44	281·94	−24·36	9·86	1·36	67·58	43·59	0·301
29	343·72	262·36	24·57	9·70	1·34	67·46	43·55	0·290
Dec. 1	343·00	242·77	24·76	9·54	1·31	67·35	43·51	0·280
3	342·29	223·16	24·94	9·39	1·29	67·24	43·45	0·270
5	341·58	203·54	25·11	9·24	1·26	67·14	43·38	0·261
7	340·87	183·92	−25·26	9·10	1·24	67·05	43·30	0·252
9	340·16	164·28	25·40	8·95	1·21	66·97	43·21	0·244
11	339·46	144·64	25·53	8·81	1·19	66·89	43·12	0·236
13	338·76	124·98	25·64	8·68	1·17	66·82	43·02	0·228
15	338·07	105·32	25·73	8·55	1·14	66·76	42·90	0·221
17	337·38	85·65	−25·81	8·42	1·12	66·71	42·78	0·214
19	336·70	65·97	25·87	8·29	1·10	66·66	42·65	0·207
21	336·03	46·28	25·92	8·17	1·07	66·63	42·51	0·200
23	335·36	26·59	25·95	8·05	1·05	66·60	42·36	0·194
25	334·70	6·90	25·96	7·93	1·03	66·59	42·21	0·188
27	334·05	347·20	−25·96	7·82	1·01	66·58	42·05	0·182
29	333·42	327·50	25·94	7·71	0·98	66·58	41·88	0·177
31	333·79	307·79	−25·91	7·60	0·96	66·59	41·70	0·172

The differences of successive values of the areographical longitude of the centre of the planet's disc amount, for an interval of two days, to about 19° less than two rotations, so that the greatest difference, at the beginning of August, is 702°·30, and the smallest, at the end of December, 700°·29.

Q denotes the position-angle and q the amount of the greatest defect of illumination, E the areocentric angle between Earth and Sun. The last column gives the ratio of the apparent brightness of *Mars* to that at mean opposition, the diminution of brightness due to the defect of illumination being assumed to depend simply on the proportion of the unilluminated portion to the whole of the disc.

The data of the ephemeris are founded upon the same elements as those for the oppositions of 1886, 1888, and 1890, and are to be interpolated directly for the times for which they are required, the equation of light having already been taken into account.

The adopted zero-meridian will apparently pass the centre of the disc at the following Greenwich mean times:—

1892.	h m	1892.	h m	1892.	h m
Apr. 30	18 35·7	May 25	10 17·1	June 19	1 44·7
May 1	19 15·1	26	10 56·1	20	2 22·8
2	19 54·4	27	11 35·1	21	3 2·0
3	20 33·8	28	12 14·0	22	3 39·1
4	21 13·1	29	12 52·9	23	4 17·1
5	21 52·5	30	13 31·8	24	4 55·1
6	22 31·8	31	14 10·7	25	5 33·0
7	23 11·1	June 1	14 49·6	26	6 10·9
8	23 50·4	2	15 28·4	27	6 48·7
10	0 29·7	3	16 7·2	28	7 26·5
11	1 9·0	4	16 45·9	29	8 4·3
12	1 48·2	5	17 24·6	30	8 42·0
13	2 27·5	6	18 3·3	July 1	9 19·6
14	3 6·7	7	18 42·0	2	9 57·1
15	3 45·9	8	19 20·6	3	10 34·6
16	4 25·1	9	19 59·2	4	11 12·1
17	5 4·3	10	20 37·7	5	11 49·5
18	5 43·5	11	21 16·2	6	12 26·9
19	6 22·6	12	21 54·7	7	13 4·2
20	7 1·8	13	22 33·1	8	13 41·5
21	7 40·9	14	23 11·5	9	14 18·7
22	8 20·0	15	23 49·9	10	14 55·8
23	8 59·0	17	0 28·2	11	15 32·9
24	9 38·1	18	1 6·4	12	16 9·9

1892.	h m	1892.	h m	1892.	h m
July 13	16 46·9	Aug. 23	17 7·0	Oct. 3	18 20·2
14	17 23·8	24	17 43·8	4	18 59·0
15	18 0·7	25	18 20·6	5	19 37·9
16	18 37·5	26	18 57·5	6	20 16·8
17	19 14·3	27	19 34·5	7	20 55·8
18	19 51·1	28	20 11·5	8	21 34·8
19	20 27·8	29	20 48·5	9	22 13·8
20	21 4·4	30	21 25·6	10	22 52·8
21	21 41·0	31	22 2·8	11	23 31·9
22	22 17·6	Sept. 1	22 40·0	13	0 11·1
23	22 54·1	2	23 17·3	14	0 50·3
24	23 30·6	3	23 54·6	15	1 29·5
26	0 7·1	5	0 32·0	16	2 8·7
27	0 43·5	6	1 9·4	17	2 48·0
28	1 19·9	7	1 46·9	18	3 27·3
29	1 56·3	8	2 24·5	19	4 6·6
30	2 32·6	9	3 2·1	20	4 46·0
31	3 19·0	10	3 39·8	21	5 25·4
Aug. 1	3 45·3	11	4 17·5	22	6 4·8
2	4 21·7	12	4 55·3	23	6 44·3
3	4 58·0	13	5 33·1	24	7 23·8
4	5 34·3	14	6 11·0	25	8 3·3
5	6 10·6	15	6 48·9	26	8 42·9
6	6 46·9	16	7 26·9	27	9 22·5
7	7 23·2	17	8 4·9	28	10 2·1
8	7 59·5	18	8 43·0	29	10 41·8
9	8 35·8	19	9 21·1	30	11 21·4
10	9 12·1	20	9 59·3	31	12 1·1
11	9 48·5	21	10 37·6	Nov. 1	12 40·8
12	10 24·9	22	11 15·9	2	13 20·6
13	11 1·3	23	11 54·2	3	14 0·4
14	11 37·7	24	12 32·6	4	14 40·2
15	12 14·1	25	13 11·0	5	15 20·0
16	12 50·6	26	13 49·5	6	15 59·8
17	13 27·1	27	14 28·0	7	16 39·7
18	14 3·7	28	15 6·6	8	17 19·6
19	14 40·3	29	15 45·2	9	17 59·5
20	15 16·9	30	16 23·9	10	18 39·4
21	15 53·5	Oct. 1	17 2·6	11	19 19·4
22	16 30·2	2	17 41·4	12	19 59·3

1892.	h m	1892.	h m	1892.	h m
Nov. 13	20 39·3	Nov. 30	7 21·8	Dec. 16	18 7·8
14	21 19·3	Dec. 1	8 2·1	17	18 48·2
15	21 59·4	2	8 42·4	18	19 28·7
16	22 39·4	3	9 22·7	19	20 9·2
17	23 19·5	4	10 3·0	20	20 49·7
18	23 59·6	5	10 43·4	21	21 30·2
20	0 39·7	6	11 23·7	22	22 10·7
21	1 19·8	7	12 4·1	23	22 51·2
22	2 0·0	8	12 44·4	24	23 31·7
23	2 40·2	9	13 24·8	26	0 12·2
24	3 20·4	10	14 5·2	27	0 52·7
25	4 0·6	11	14 45·6	28	1 33·2
26	4 40·8	12	15 26·0	29	2 13·7
27	5 21·0	13	16 6·5	30	2 54·2
28	6 1·2	14	16 46·9	31	3 34·7
29	6 41·5	15	17 27·3		

Col. Cooper's Observatory:
Markree, Collooney, Ireland.

Errata in Mr. Jacoby's Papers.

Page 109, opposite $\phi = 37^\circ\ 50'$, column A, *for* 1 35 57·93 *read* 1 34 57·93

" 110 " $\phi = 40$ 10 " y " +·0663 *read* +0563

" 113 " $\phi = 54$ 20 " y, insert the difference 6

" *ib.* " $\phi = 55$ 0 " x (difference), *for* 74 *read* 72

" 115, line 15, *for* of the *read* after

" 115, in the equation strike out letter B

" 116, equation (a), in first term, *for* z *read* x

Erratum in Professor Oudemans' Paper.

At bottom of page 159 (before the note) add the following words:

Accordingly, in my opinion, the dark line seen October 29 and November 3 must be taken for the dusky ring, projected on the planet.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LII. APRIL 8, 1892. No. 6

Edward James Stone, M.A., F.R.S., Vice-President, in the Chair.

Louis Joyner, Bermuda;
Belgrave Ninnis, M.D., R.N., F.R.G.S., 46 Kensington Park Road, W.;
John Krom Rees, A.M., E.M., Director of the Observatory and Professor of Practical Astronomy and Geodesy, Columbia College, New York City, U.S.A.;
William James Watson, Morley House, South Stockton-on-Tees;

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

The Rev. James Baikie, Wood Inch, Dalguise, near Dunkeld, Scotland (proposed by W. S. Franks);
John Dansken, 4 Eldon Terrace, Partick, Glasgow (proposed by R. Grant);
Henry Daniel McCarthy, Cheltenham (proposed by J. McCarthy);
Martin Charles Sharp, M.A., 5 Portman Street, Portman Square, W. (proposed by T. H. E. C. Espin).

Sixty-one presents were announced as having been received since the last meeting, including, amongst others,

Observatoire de Nice: portfolio of engravings and plans, presented by M. Bischoffsheim.

Astronomical Telegrams.

At the Council Meeting on 1892 April 8, attention was called to the suggestion recently made, that the Society should become an English centre for the distribution of astronomical telegrams. It did not appear desirable to consider any course of action independent of the already existing "Centralstelle für Astronomische Telegramme" at Kiel, and a letter from Prof. Krueger (printed below) was laid before the Council. It appeared that there would be some advantages in a scheme whereby the telegrams of the Centralstelle should be sent direct to the Society's rooms, and each then distributed by Mr. Wesley (or his deputy, when away) to such Fellows (or others) as became subscribers. But it seemed necessary that a preliminary inquiry should be made as to the number of possible or probable subscribers; and the Secretaries were accordingly instructed to draw up the present note, requesting those willing to subscribe to send their names to the Secretaries without delay, in order that the Council might then judge of the desirability of the scheme. The following is Prof. Krueger's letter, received in reply to an inquiry by the Secretaries:

"DEAR SIR,—I have been away for a few days, and am thus only able to answer your letter of March 28 to-day.

"There is no reason why the R.A.S. should not receive the telegrams of the Centralstelle for redistribution. But it must be made a condition that those persons or observatories who receive our telegrams through the R.A.S. take their share in the total expenses of the Centralstelle. This arrangement is already in existence with the Russian observatories. I only send telegrams (as regards Russia) to Pulkowa, and Pulkowa telegraphs on to all Russian observatories. At the end of the year it is calculated how much is spent on telegrams to Pulkowa; this is divided among the Russian subscribers, and, in addition, it is calculated how much each subscriber must pay towards the general expenses of the Institution.

"If the R.A.S. will undertake the part of an English centre, the subscription for the R.A.S. for the first year would be 3*l*., and 1*l*. for each subscriber who receives the telegrams. I assume that the Planet telegrams are not wanted, since no one in England has yet cared to follow these objects. If these were included, the subscription for the R.A.S. for the first year would be about 4*l*. For the next year the estimated subscription for the R.A.S. would be about 2*l*., and at most 1*l*. for the subscribers, again without minor Planets; otherwise 3*l*. to 4*l*. for the R.A.S.

"The more subscribers the cheaper will be the expenses of the Institution. An accurate calculation is made for each subscriber at the year's end, and an estimate made for the following

year. The actual expenses have hitherto always been smaller than the estimated, and the excess is, of course, always credited in the next year. Under such an arrangement the R.A.S. must collect from the subscribers the cost of telegrams sent in England. I enclose forms for our telegrams; these could, if you wish, be translated into English. They have as yet been found suitable for the purpose, and would not be changed except for urgent occasions.

"It is much to be wished that the matter may soon be arranged; up to now Greenwich and Edinburgh are the only English subscribers, while a large part of the Continent, the United States, South America, Cape Town, Madras, and Melbourne are associates. If we could get a dozen observatories from England as new subscribers, the general expenses of the Institution would be reduced, and the success of the undertaking greatly enhanced.

"Should, however, the R.A.S. not care to undertake to be sub-centre for England, it is at least to be wished that English astronomers should be advised to join the Centralstelle in as large a number as possible. The annual cost is small, especially if no minor planets are wanted. I hope you will soon be able to send me news of the development of the scheme.

"Yours, &c.,

"To H. H. Turner, Esq. "A. Krueger.

"P.S.—If the R.A.S. takes over the distribution for England, it would be the simplest course to tell me how many subscribers you would have, and I would then estimate:—

"1. Cost of telegrams to the R.A.S.

"2. General expenses for R.A.S., and the individual subscribers.

"The R.A.S. could pay the whole to the Centralstelle and collect the shares from each subscriber, so that we should only deal with the R.A.S.

"Recently I have thought of another way of dealing:—That the R.A.S. should pay an annual fixed sum to the Centralstelle, and make its own arrangements with subscribers. But I cannot decide on this point, which must be reserved for the decision of the Committee."

If ten subscribers be found, the following would seem to be the advantages of this scheme compared with a direct subscription by each of the ten to the Centralstelle:—

1. The cost would be somewhat reduced, but not very materially. The reduction would be approximately the difference between the price of foreign telegrams and those of English, but not quite, for there is in each case one additional foreign telegram (to the R.A.S.) the cost of which must be shared by the ten subscribers. The contribution of each subscriber for the office

expenses of the Centralstelle would be much the same as if he subscribed directly to the Centralstelle (if expenses incurred by the R.A.S. be distributed among the ten subscribers). But the reduction of the telegraphic expenses may be best shown by an example.

On an average twelve telegrams are sent from Kiel per annum with reference to the discovery of minor planets, and a like number with reference to the discovery of comets and other objects of interest; the average number of words in each telegram, exclusive of the address, being about fourteen. It is possible, as Prof. Krueger points out, to subscribe to the Centralstelle for all telegrams, or to have a partial subscription, in which case discoveries of minor planets are not notified. Supposing, then, that twelve telegrams, each of eighteen words (including address), were received during the year, the cost to a direct subscriber to the Centralstelle would be 216 × 2*d.* = 1*l.* 16*s.*; but to a subscriber through the R.A.S., if ten subscribers joined, it would be one-tenth of this (or 3*s.* 8*d.*) plus the cost of English telegrams = 9*s.*, or 12*s.* 8*d.* in all—a reduction of 1*l.* 3*s.* 4*d.*

2. The few German words used could be translated into English. But the telegrams are mainly in cipher.

3. English discoveries, communicated directly to the R. A. S., could be circulated immediately without passing through the Centralstelle.

The disadvantages would appear to be

1. The slight delay in re-distribution with possibility of accident to the main telegram.

2. The extra work and responsibility thrown on the paid Secretary of the Society (or his deputy). In view of these considerations, the Council will be guided in their decision to a great extent by the number of possible subscribers; and it is hoped that those interested will communicate with the Secretaries as soon as possible.

Note on the Lunar Theory. By Ernest W. Brown, M.A.

In determining the coefficients of the inequalities in the Moon's motion, which depend on the eccentricity and the ratio of the mean motions of the Sun and Moon, it is important to have the motion of the perigee of the Moon accurately determined. I have completed the determination of those coefficients which are of the form $e\,f\,(m)$, and in particular that part of the evection which is of the above form. The determination of the part of the motion of the Perigee required for this involves the solution of an infinite determinant. In vol. viii. of the *Acta Mathematica* Dr. Hill has, however, found a value for this

quantity calculated to fifteen places of decimals. This value I have succeeded in verifying as far as nine places of decimals, by proceeding in an entirely different manner. His value is

$$\frac{1}{n} \cdot \frac{dw}{dt} = 0{\cdot}008572573004864.$$

Using this, the following coefficients in longitude were obtained for those parts which are of the form $e\,f\,(m)$:—

$$\begin{aligned}
&+4607''{\cdot}9836 \sin(2\,D - l) + 35''{\cdot}2200 \sin(4\,D - l)\\
&+0''{\cdot}2906 \sin(6\,D - l) + 0''{\cdot}0028 \sin(8D - l)\\
&+174''{\cdot}8610 \sin(2\,D + l) + 1''4460 \sin(4\,D + l)\\
&+0''{\cdot}0121 \sin(6\,D + l) + 0''{\cdot}0001 \sin(8\,D + l)
\end{aligned}$$

These values are all correct to the last decimal given. The notation is the same as in Delaunay's Lunar Theory, and his value of the eccentricity, for purposes of comparison, has been used. The results, however, are adapted for any value of the eccentricity with the given one for the mean motions. It may be stated that Delaunay's value for the corresponding part of the evection in longitude is

$$4607''{\cdot}7710.$$

I hope before long to publish the complete determination of all the inequalities depending on the eccentricity and mean motions, including that part of the motion of the perigee which depends on the eccentricity of the Moon. This will amount to a general solution in series of Dr. Hill's equations.*

$$\begin{aligned}
&\frac{d^2x}{dt^2} - 2n'\frac{dy}{dt} + \left(\frac{\mu}{r^3} - 3n'^2\right)x = 0\\
&\frac{d^2y}{dt^2} + 2n'\frac{dx}{dt} + \frac{\mu y}{r^3} \qquad\qquad = 0
\end{aligned}$$

In this solution the eccentricity of the Moon is left arbitrary.

Haverford College:
1892 *March* 28.

* *Amer. Journ. Math.*, vol. i. p. 129.

Observations of the Spots and Markings on the Planet Jupiter, made at the Dearborn Observatory, Northwestern University, Evanston, U.S.A. By G. W. Hough, Director.

The observations for longitude, latitude, and magnitude of objects on the planet *Jupiter* have all been made with the parallel wire micrometer, preferably near the central meridian, but no rigid rule is followed in this respect. The longitude and latitude are usually determined whenever the spot or marking is wholly on the disc and distinctly visible.

The longitudes are ascertained by measuring the distance of the apparent centre of the object from the two limbs of the planet, according to the method I pointed out some years ago. A determination of longitude or latitude generally consists of three bisections of the object and each limb of the planet. In the case of longitude, one-half of the difference of the distances at the mean of the times is the distance of the apparent centre of the object from the central meridian of the visible disc. This method of determining longitudes has been found to be greatly superior, in point of accuracy, to the method of transits, as well as a great saving of time.

Professor Barnard, of the Lick Observatory, in the publications of the Astronomical Society of the Pacific, No. 5, and in the *Monthly Notices of the Royal Astronomical Society*, 1891 November, on insufficient data, has too hastily assumed that the method of eye estimates, or transits, may be as accurate as micrometer work.

My observations on the planet *Jupiter* with the 18½-inch refractor of the Dearborn Observatory have been continuous since 1879, with the exception of the opposition of 1888 and a portion of 1889, during which period the telescope was dismounted for removal to the new site at Northwestern University.

The great red spot, owing to its long period of visibility, is perhaps the most interesting object on the disc. Since its observation in 1878, *Jupiter* has made a complete revolution in his orbit, and the red spot appears to have preserved its outline, shape, and size with very little change during the whole period.

There has been marked fluctuation, however, in its colour and visibility, the spot at times being so faint as to be invisible with small telescopes.

During the past twelve years a number of observers have asserted at different times that the red spot was connected with, or merged into, a belt in its immediate vicinity. This matter was fully discussed some years ago, and I inferred from what was then said that it was the general opinion of all astronomers who used sufficient optical power, that the spot was at all times separate, although in close proximity to other matter.

During 1889 and 1890 the planet was too far in south declination to afford any definite information. So far as my

observations go, however, the spot has always been distinct and separate from surrounding matter, apparently exerting a repelling force, as I stated in my Annual Report for 1883.

During the past opposition, under favourable conditions the spot was noted as pale pink, being similar in tint to what it was in 1879–80, but the colour was not so intense. The spot this year was not so strongly defined as the equatorial belt.

In the comparison of observations for latitude, made in different years, it is more convenient to use the distance from the equator expressed in seconds of arc, reduced to mean distance.

If the Jovicentric or Jovigraphic latitude of a spot is given, one does not know where to look for it on the disc unless the latitude is reconverted into seconds of arc.

I have, therefore, added the reduced latitude, obtained by applying the correction for the elevation of the Earth above *Jupiter's* equator. This correction is given in degrees in Marth's invaluable Ephemerides, published annually in the *Monthly Notices* of the Royal Astronomical Society.

In computing the correction to be applied to the apparent latitude, I have used the values $18''\cdot33$ and $19''\cdot48$ for the semi-axes of the planet at mean distance.

These values for the size of the disc were found from a great many differential measures made in 1880–81, and are somewhat larger than those given by heliometer measures, owing to irradiation, but they will probably better satisfy micrometer work.

In the determination of rotation period, the observations have been corrected for longitude of equinox, aberration time, annual parallax, and defective illumination. With the exception of the longitude of equinox, all the other corrections have been taken from Marth's Ephemerides.

The time used is that of the 90th meridian west from Greenwich.

The Great Red Spot.

The following rotation periods will indicate the motion of the great red spot since last year:—

1890 July 1 to 1890 Dec. 8, (160 days),

$R = 9^h\ 55^m\ 39^s\cdot75$

1890 July 1 to 1891 May 25, (328 days) 39·96 secs.

1890 Dec. 8 to 1891 May 25, (168 „) 40·10 „

1891 May 25 to 1892 Jan. 22, (242 „) 41·27 „

These numbers indicate that the spot has not yet ceased to retrograde.

During the past opposition the "mean" period $41^s\cdot27$ does not satisfy the observations, but a uniformly retarded velocity represents the motion fairly well. I have given in col. 4 the residuals (Observation − Ephemeris) for a uniform rotation $41^s\cdot27$, and in col. 5 the same for a retarded motion, $R = 9^h\ 55^m\ 40^s\cdot0$

$+n \times 0^s{\cdot}005$, in which n equals the number of rotations from the epoch 1891 May 25.

For a uniform rotation period the "mean" residual (Obs.—Eph.) is $\pm 1^m{\cdot}7$, and for a retarded rotation $\pm 1^m{\cdot}2$.

T = Time of passage over the central meridian.

L = Length of chord on middle of disc.

B = Breadth.

β = Apparent latitude.

The length of the great red spot appears to be about 1″ shorter than in former years. In 1890 the length from two measures was 11″·49. In 1889 the spot was too indistinct for reliable measures of length.

The Great Red Spot.

Date 1891	Days	T h m	$41^s{\cdot}27$ Obs.-Eph. m	$40^s + n \times 0^s{\cdot}005$ Obs.-Eph. m	L ″	B ″	β ″
May 25	0	14 29·7	+2·7	+1·0	...	...	...
July 5	41	13 20·8	+1·0	+0·9	...	...	−7·21
9	45	16 38·4	+2·1	+2·1	10·24	4·09	6·63
14	50	...	...	...	...	3·83	7·00
20	56	10 38·9	−3·8	−3·4	10·36	4·69	6·84
22	58	12 19·2	−1·7	−0·7	11·18	...	...
26	62	15 32·9	−4·3	−3·7	...	...	7·09
Sept. 6	104	10 13·0	−0·1	−0·1	...	...	...
9	107	7 39·8	−2·2	−1·3	...	...	6·35
11	109	9 20·1	+0·2	+1·2	...	...	7·19
16	114	8 22·1	−5·0	−3·9	...	...	7·49
21	119	7 34·5	−0·1	+0·8	...	...	7·30
3	121	9 12·4	−0·3	+0·4	9·85	4·95	...
25	123	10 51·6	+0·7	+1·4	10·48	4·50	6·82
Oct. 5	133	9 07·4	+0·9	+1·8	...	...	7·27
7	135	10 44·9	+0·1	+0·9	...	...	7·30
22	150	8 08·8	−0·8	−0·3	...	...	7·08
27	155	7 18·7	+0·5	+0·8	...	...	6·56
Nov. 17	176	9 42·4	+1·1	+0·9	...	...	6·68
30	189	5 34·4	+2·9	+0·5	...	...	6·54
Dec. 29	218	4 41·3	+2·6	+0·5	...	...	7·13
1892 Jan. 22	242	4 41·6	+3·5	+0·0	...	...	...

Mean Length ... 10″·42 (5 obs.)

„ Breadth ... 4·41 (5 obs.)

Reduced Latitude −6·52 (17 obs.)

Dark Spots on B_6.

During the opposition of 1891, three separate spots were observed on this belt, two of which were distinctly red in colour and of considerable length. The third spot appeared as a dusky hazy patch, and was $0''.7$ farther south.

The rotation periods for these objects were $9^h\ 55^m\ 20^s$ and $9^h\ 55^m\ 0^s.3$.

Long. Red. B_6.

$R = 9^h\ 55^m\ 20^s$.

Date. 1891.	Days.	T h m	Obs.-Eph. m	L "	B "	β "
July 3	0	16 41·7	−2·4	...	...	−8·23
8	5	15 48·8	+1·0	7·26	...	9·02
15	12	16 30·7	+3·0	7·67	1·05	9·59
28	25	11 59·6	−1·7	...	...	9·20
Sept. 7	66	10 10·5	−1·2	7·91	1·03	8·54
15	74	6 45·1	+3·8	...	...	8·66
22	81	7 22·3	+1·4	...	...	8·80
24	83	8 57·0	−0·3	...	...	...
29	88	7 56·8	−4·1	7·49	1·31	8·63
Oct. 9	98	6 12·0	+3·6	...	...	...
16	105	6 48·0	−1·1	...	...	...
28	117	6 32·7	−2·0	...	...	...

Length ... ... 7''·58 (4)
Breadth ... ... 1·13 (3)
Reduced Latitude −8·34 (8)

Long. Red. B_6.

$R = 9^h\ 55^m\ 03^s$.

Date. 1891.	Days.	T h m	Obs.-Eph. m	L "	β "
Nov. 5	0	7 05·6	+0·0	11·00	...
26	21	8 58·2	+3·3	12·23	−8·64
18	43	6 35·9	+0·1	...	...

Length ... ... 11''·61 (2)
Reduced Latitude −8·24 (1)

Dusky Black Patch. B_6.

$R = 9^h\ 55^m\ 20^s$.

Date.	Days.	T	Obs.-Eph.		β
1891.		h m	m		"
Sept. 10	0	9 33·7	+0·0	...	−9·41
Oct. 9	29	8 05·3	+1·4	...	...
14	34	7 06·2	−1·6	...	9·37
16	36	8 45·9	+1·3	...	9·47
21	41	7 47·2	−1·6	...	9·46
Nov. 2	53	7 36·8	+2·2	...	...
Dec. 18	99	5 09·0	+0·1	...	...

Reduced Latitude $-9''\cdot01$ (4)

Dark Spots on the North Edge of the Equatorial Belt.

During the opposition of 1890, from June 12 to October 20, five small reddish black spots were observed on the north edge of the equatorial belt; two of these spots have been observed again in 1891.

The rotation periods for the several spots observed in 1890 were as follows:—

	h m s	days
a =	9 55 34·0	130
b =	33·3	179
c =	„ „ 36·6	70
d =	„ „ 32·0	108
e =	36·6	7

The spots a and b were observed in 1891. The mean longitude of b with reference to a was as follows:—

	m
1890	+40·2
1891	+24·8

The following are the rotation periods for the spot a:—

1890 June 12 to 1890 Oct. 20 130 days

$R = 9^h\ 55^m\ 34^s\cdot0$

1890 Oct. 20 to 1891 July 9	262 days	$31^s\cdot4$
1891 July 9 to 1891 Nov. 5	119 „	$27^s\cdot4$

These numbers indicate a pretty uniform decrease in the rotation period.

Spots a and b, North Edge of Equatorial Belt.

R = $9^h\ 55^m\ 27^s.4$

Date.	Days	T	$b\Delta t$	Obs.-Eph.	β
1891.		h m	m	m	"
July 9	0	14 01·1	...	+0·0	...
Sept. 8	61	8 43·3	22·6	+1·7	+4·36
10	63	10 17·3	23·8	−3·0	...
15	68	9 23·8	25·0	+0·9	...
25	78	7 37·4	25·7	+5·1	4·17
29	82	10 45·3	27·8	−1·1	...
Oct. 2	85	8 13·8	25·8	−0·4	...
9	92	8 54·5	26·2	−2·1	3·87
Nov. 2	116	8 33·6	21·9	−0·4	...
5	119	6 01·8	...	+0·7	...

Mean difference of Longitude *a* and *b*, $24^m.8$

Reduced Latitude $+4''.67$ (3)

Small Black Spots on B_2.

A number of small black spots were seen in reduced latitude $+9''.34$, but accurate longitudes were not determined. In 1880, from August to October, two small black spots were observed in latitude $+11''.0$. The rotation periods were $9^h\ 55^m\ 31^s.0$ and $40^s.5$ respectively. See Report of the Dearborn Observatory, 1881.

Small Black Spots on B_3.

During the past opposition a great number of small black spots were seen on the south margin of this belt, appearing like a row of beads, making it difficult to identify individual spots. The longitudes of three of these spots, the first of a row, were accurately determined on two successive nights, and when compared with Marth's Meridian II. they indicated a gain of $7^m.5$ daily, or a rotation about 3^m less than the great red spot.

The following are the times of transit:—

	h m	h m	h m
Sept. 7	11 14·1 (*a*)	11 30·7 (*b*)	12 03·1 (*c*)
Sept. 8	6 56·5 (*a*)	7 14·6 (*b*)	7 47·8 (*c*)

Additional spots:—

	h m	h m	h m
Sept. 8	8 06	8 23	8 36
„	8 57	9 27	9 52

Latitude observed :—

Sept. 7	$+6''.11$	Sept. 25	$+6''.34$	Oct. 9	$+5''.64$
Nov. 24	$+6.15$	Dec. 11	$+6.06$		

Reduced Latitude $+6''.56$ (5 obs.)

I observed spots on this belt in 1880–84.

Elliptical White Spots on B_6.

During every opposition since 1880 elliptical white spots have been observed on a belt just south of the great red spot. These spots usually have a drift in the direction of the planet's rotation when referred to the great red spot.

The spots whose longitudes were determined in 1891 had a direct motion of about $0^m.9$ daily.

The following transits have been observed :—

Date.	T	β	
1891.	h m	$''$	
Sept. 25	9 47.5	-9.10	Group of spots.
25	10 01	...	
25	10 16 (*c*)	...	
25	11 02.3	...	
Oct. 22	9 01.4 (*a*)	-9.12	
27	8 01.7 (*a*)	-9.25	
29	7 53.4 (*c*)	...	
Dec. 29	4 24.0 (*a*)	...	

Reduced Latitude $-8''.71$ (3)

On the south margin of B_6, in reduced latitude $-10''.7$, elliptical white spots have been observed at every opposition since 1880. These spots are the most difficult of any of the markings visible on the planet, and can only be seen under favourable atmospheric conditions. The rotation period deduced from them is approximately the same as for the great red spot. In 1883, however, they had a retrograde drift of 1.2 degrees daily, or a rotation period 50 seconds greater than the great red spot.

Equatorial White Spots.

The equatorial belt was usually mottled with white spots on both the northern and southern portion, but none of the spots were particularly conspicuous.

Date	Days	T	Obs.-Eph.	β	Remarks.
1891		h m	m	"	
July 8	...	15 34·3	...	−2·32	Double Spot
9	...	14 50·9	...	+2·19	Double Spot
15	...	16 18·5	...	−3·30	
15	...	16 04·0	...	+2 (est.)	
Sept. 10	0	9 43·5	+ 0·0	+2·20 (*a*)	
10	...	9 57·9	+ 0·0	−3·32 (*b*)	Spot foll. $8^m \cdot 6$, $0'' \cdot 5$ south
29	...	8 22·0	...	+2·01	
Oct. 16	...	9 00·0	...	−3 (est.)	
Nov. 2	53	7 30·9	+12·0	+1·48 (*a*)	
2	...	7 30·9	+ 9·0	−3·00 (*b*)	
18	69	7 11·0	− 0·9	+1·95 (*a*)	
18	...	7 11·0	− 0·9	−1·43 (*b*)	
Dec. 18	99	5 35·1	− 7·7	−2·20 (*b*)	

The approximate rotation periods are

$$a = 9^{h}\ 50^{m}\ 31^{s}\cdot 6,\ 69 \text{ days, Reduced latitude } +2''\cdot 67\ (3)$$
$$b = 9\ 50\ 26\cdot 4,\ 99\ \text{„}\qquad \text{„}\qquad \text{„}\qquad -2\cdot 00\ (4)$$

The motion was not uniform.

The Equatorial Belt.

During the past two years the great equatorial belt has been quite open. At times, however, a faint marking has extended over the middle portion. The approximate width of the open part in 1890 was $2''\cdot 6$, and in 1891 $3''\cdot 1$, or about one-third of the total width of the belt.

During the past thirteen years the belt has usually been separated in two portions by a rift, but at times, notably in 1879 and 1880, the belt was made up of three nearly equal portions, the central one being midway between the other two.

In the observations which follow, the 2nd col. is the approximate longitude in time, from Marth's Meridian II.; 3rd col., position angle of the north edge of the belt; 4th col., comparison with Marth's ephemeris for *Jupiter's* equator; 5th col., apparent latitude of the north edge; 6th col., width of the belt.

The comparison with the ephemeris indicates that the north edge of the belt was parallel to *Jupiter's* equator.

The Equatorial Belt.

Date.	Long.	P	Obs.-Eph.	β	W
1891.	h	°	°	″	″
July 3	+3·3	64·1	-0·7	+3·76	9·31
8	+4·3	63·6	−1·2	3·60	8·80
9	−1·5	...	...	4·19	...
14	+0·0	64·4	−0·4	...	...
15	+3·7	65·1	+0·3	3·21	9·11
20	+0·6	67·1	+2·2	3·40	9·98
23	−3·5	63·6	−1·3	3·74	...
26	+0·0	65·6	+0·7	...	...
Sept. 8	−3·7	65·2	−0·1	4·36	7·93
21	+0·5	64·2	−1·3	...	...
25	−2·3	65·5	−0·0	4·17	7·16
29	−5·8	65·8	+0·2	...	9·30
Oct. 7	−0·3	66·4	+0·7	3·67	7·88
9	+1·5	...	...	3·87	...
20	+1·6	65·3	−0·5	3·78	9·51
Nov. 2	−4·0	65·9	+0·1	...	...
24	−2·0	...	...	3·49	7·67
26	−3·8	67·1	+1·4	...	8·22
Dec. 11	−1·5	65·7	+0·2	3·13	7·96
18	−4·5	64·3	−1·1	...	...
29	+0·5	64·8	−0·5	...	...

Inclination of the North Edge of Equatorial Belt to Equator = −0°·07

Reduced Latitude	+4″·25	(13 obs.)	
„ „	+4·79	(13 obs.)	1890
Mean Width	8·57	(12 obs.)	
„ „	10·42	(9 obs.)	1890

Theory of Jupiter.

In my annual Report of the Dearborn Observatory, 1881, I gave the following hypothesis—viz., "That the surface of the planet is covered with a liquid semi-incandescent mass, that the belts, the great red spot, etc., are matter at a lower temperature. Over the liquid surface is an atmosphere, in which is formed the equatorial white spots, which are of the nature of clouds."

I still think that the lower surface of the planet is of the nature of a liquid, but not necessarily hot.

Observations of the Reappearance of the Rings of Saturn; Observations of the Position-Angles of the Rings, and Observations of the Satellites. By E. E. Barnard.

The conditions for observation at the reappearance of the rings of *Saturn* in 1891 were somewhat better than those at the disappearance in 1878. Neither the reappearance of 1878 nor the disappearance of 1891 could be observed on account of the proximity of the planet to the Sun.

At the present reappearance of the rings, the planet was situated in the morning sky, two hours and a half west of the Sun, and in three and a half degrees north declination.

From Professor Hall's valuable memoir on *Saturn* (being Appendix II. of *Washington Observations for* 1885) we learn that with the 26-inch the rings were wholly invisible at the disappearance of 1878, except where they were projected on the ball of the planet. Since the reappearance of *Saturn* from the region of the morning Sun, I have examined it carefully a number of times with the 12-inch, and on two occasions, when the opportunity permitted, with the 36-inch.

Up to October 29, on no occasion, with the most careful scrutiny and good seeing, was it possible to detect the slightest trace of the rings projected on the sky, though they appeared as a heavy black band crossing the planet and apparently cutting it nearly in halves.

On October 22 *Saturn* was carefully examined with the 36-inch, but the rings were equally invisible in that instrument. The observations extended from $17^h\ 15^m$ to $18^h\ 15^m$ Standard Pacific time (8^h slow of Greenwich). The seeing was 3 on a scale of 5 for perfect steadiness. The projection of the ring on the ball was perfectly black. The edges were sharp and perfectly free from irregularities, and no evidence of the crape ring was seen. The southern edge of the trace was slightly convex. Only one belt was visible, and that was some $3''$ south of the ring.

I very carefully measured the width of the projection of the ring at its middle part on the ball. This could be done with great accuracy by placing the wires so that their outer edges exactly filled the black trace, the measures being corrected for the thickness of the wires ($0''{\cdot}12$). The resulting value, at $18^h\ 0^m$, gave the width of the middle of the projection $= 0''{\cdot}51$. This agrees exactly with the value derived from the data in the American Ephemeris ($0''{\cdot}51$).

The measured distances of the centre of the projection from the polar limbs of *Saturn* were

$$\text{From north limb} = 7''{\cdot}40$$
$$\text{From south limb} = 6{\cdot}56$$

[illegible] of the [illegible] however [illegible] in [illegible] [illegible] the [illegible] pro[illegible] [illegible] After [illegible]

[illegible] glance [illegible] ntion [illegible] phen[illegible] [illegible]

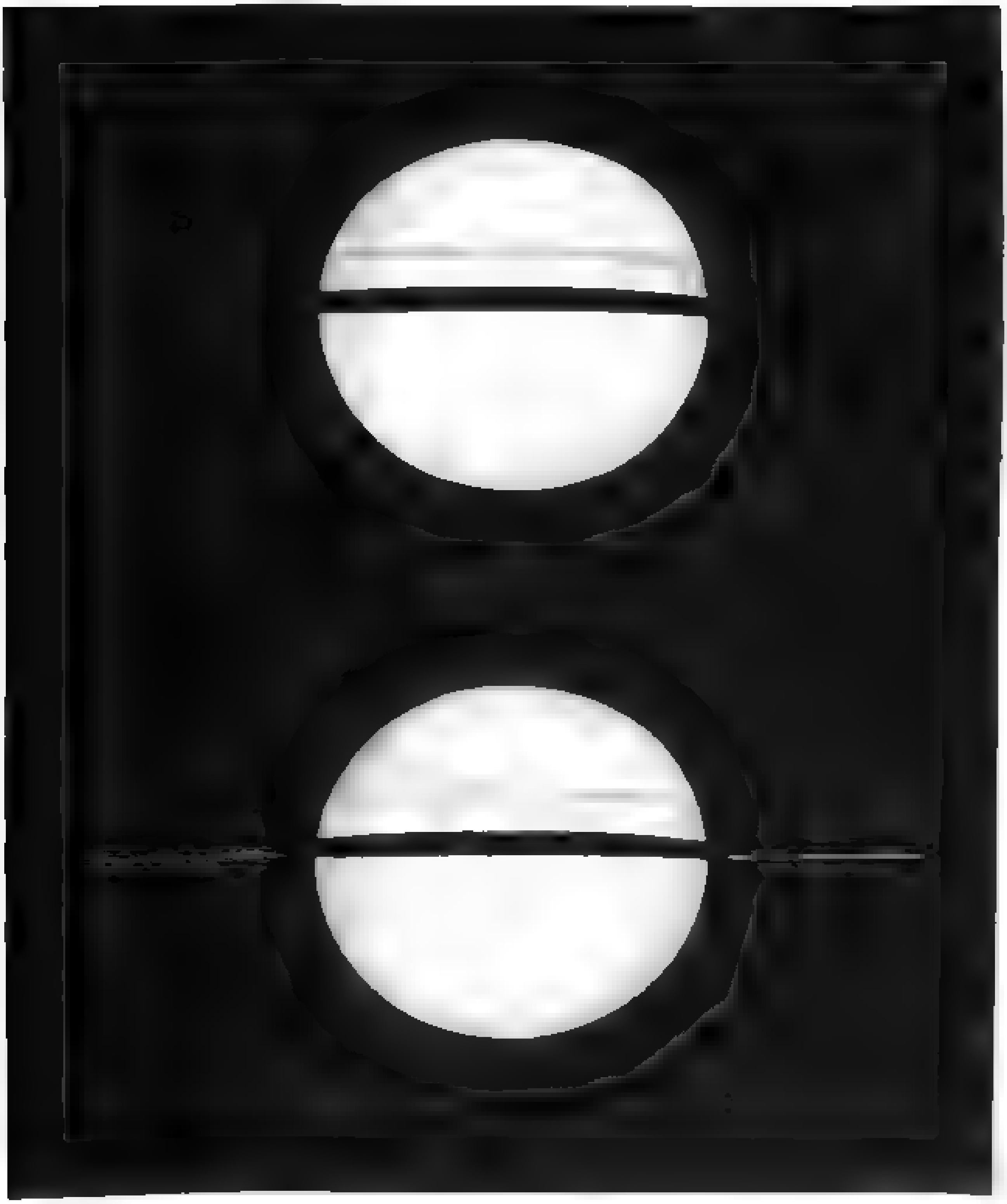
[illegible] ation [illegible] sible, [illegible] near the [illegible]

[illegible] looked [illegible] of the rings [illegible]

[illegible]

At [illegible] The rings [illegible] w[illegible] visible, [illegible] [illegible]

At the [illegible] the [illegible] the plane of the rings, [illegible] Sun was exactly in the [illegible] according to the [illegible]



Saturn 1891 October 22 and 29
36 inch Refractor, Lick Observatory.

Diagram Oct. 29 1891 Saturn
Showing the positions of the two irregularities on the Ring
17h 30m

The following notes were made, among others, during these observations:—

October 29.—The following ansa appears the brighter. There are two little lumps on the south edge; possibly two satellites. Rings not seen up to ball. They would touch the planet, if continued, *north* of their trace on *Saturn*.

November 3.—The preceding ansa is the brighter, and appears uneven. Rings cannot be seen up to ball; continued, they would pass *north* of their trace on the planet. The rings are very pale and their light weak, compared with the ball. Trace very black.

November 5.—Possibly the following end is the brighter.

November 6.—Possibly the following end is the brighter.

In all the observations the projection of the ring on the ball was perfectly black, and no trace of the division could be seen.

In the drawing of October 29 I have not attempted to show the two inequalities on the following ansa. They were quite difficult, and any attempt to show them on the drawing would be an exaggeration. I therefore append a small diagram, given on the plate, which will show their position. I assume they were two of the inner satellites.

No spots, dark or light, have been seen on the ball of *Saturn* at any time during the observations.

The observations with the two telescopes during October confirm the extreme thinness that has been attributed to the rings. Under more favourable circumstances of observation it is possible that they may be visible in the 36-inch, but at the disappearance of the past year they were certainly beyond reach of both instruments.

It is probable that the rings are less than 50 miles in thickness.

In *Monthly Notices* for January, 1892, Professor Oudemans gives an account of his observations of the reappearance of the rings of *Saturn* with the $9\frac{1}{2}$-inch equatoreal of the Utrecht Observatory.

Professor Oudemans says that on October $29^d\ 17^h\ 30^m$ (= October $29^d\ 9^h\ 3^m$ Mt. Hamilton M. T.) *Saturn* was decidedly without any ring. October 30 was cloudy, but on October 31, at $17^h\ 30^m$, a momentary view showed the ring at both sides of the planet as a thin bright line.

Combining my observations of October 29 with those of Professor Oudemans for the same date, it is evident that the time of reappearance of the ring is narrowed down to the interval between $9^h\ 3^m$ and $17^h\ 0^m$, October 29^d, 1891, Mt. Hamilton M. T. The American Ephemeris gives October 30 as the time of reappearance.

In the *Monthly Notices* for November, 1891, the Rev. Mr. Freeman has given his observations of the reappearance of the ring with a 6-inch refractor.

October 29^d 18^h 10^m to 18^h 35^m G. M. T., he saw nothing of the ring.

October 30^d 18^h 25^m to 18^h 35^m he was also unsuccessful.

But on November 1^d 17^h 30^m G. M. T., he plainly saw it as a fine bluish line of light. From his observations he deduces October 31^d 18^h G. M. T., 1891, as the time of the passage of the plane of the rings through the Sun.

Mr. Freeman's telescope was too small to show the ring early enough, and his data will therefore be insufficient to determine the position of their plane.

Position Angles of the Rings.

In the *Astronomical Journal*, No. 246, I have given a number of measures of the position angles of the rings of *Saturn* with the 12-inch, and a comparison with the American Ephemeris values.

From these observations (on thirty nights) I deduced a correction of $-3'\cdot36 \pm 1'\cdot68$ to the position angles derived from the Ephemeris. Since the reappearance of the rings I have continued these measures. Following are the observations so far continued:—

Observations of the Position Angles of Saturn's Rings.

1891–92.	Mt. Hamilton M.T.	P.A.	Set.	See.	C—O.
	h m	°			°
Oct. 22	17 30	85·70	4	3	−0·23
29	17 30	86·10	5	...	−0·55
Nov. 3	17 8	85·83	5	5	−0·19
5	17 33	85·46	5	2	+0·13
6	17 0	86·14	4	2–3	−0·54
21	17 27	85·62	5	2	+0·11
27	17 30	85·76	5	4	+0·01
Jan. 10	14 4	86·03	4	4–5	−0·12
Mar. 8	15 57	85·69	5	4–5	0·00
9	8 54	85·75	5	5	−0·07
16	9 26	85·68	5	4–5	−0·05
		Mean deviation		... ...	−0·14

These observations give a correction of

$$-8'\cdot40 \pm 1'\cdot02$$

to the Ephemeris.

The measures in October and the first part of November were made under unfavourable conditions compared with those printed in the *Astronomical Journal*, and should have less weight.

Conjunction of the Satellites with the Ring.

The following observations of the satellites of *Saturn* have been made. These observations will be continued. Absence from the Observatory during the latter part of January, February, and a part of March has prevented more observations of the satellite so far this year.

Conjunction of Tethys and following end of Ring.

1892.	h	m	s	
Jan. 10	14	9	18	*Tethys* ½ thickness of wire following.
	14	12	43	" ¼ " " "
	14	15	53	Conjunction.
	14	19	28	*Tethys* past conjunction by ¼ thickness of wire.
	14	22	58	" " " ½ " " preceding thickness of wire 0″·44. Mag. power 175 on 12 in.

Conjunction of Rhea and following end of Ring.

Rhea North.

	h	m	s	
Jan. 22	15	28	11	*Rhea* 1 thickness of wire preceding end of Ring.
	15	31	31	" ½ " " " "
	15	35	31	*Rhea* in conjunction with following end of Ring.
	15	42	21	½ thickness of wire following end of Ring.
	15	47	21	1 " " " "

In these observations the micrometer wire was made vertical to the ring. The moment of conjunction could be quite closely observed, as any displacement was easily seen by bisecting the satellite or the end of the ring.

Mount Hamilton:
1892 *March* 17.

Note on the Transit of Titan, 1892, *March* 11. By Arthur Mee.

This evening, with pretty fair definition, I had been observing the Moon, and afterwards (about 10.15) turned my 8½ in. Calver equatoreal on *Saturn*. I immediately saw, a little way within the southern limb, and slightly east of the meridian, a dark spot, and almost immediately afterwards a brown spot still further to the east. I watched the pair with powers 200–400 till I had to leave the telescope. The dark spot seemed central at 10.30. Looking up the almanac next day, I found the dark spot was the shadow of *Titan* in transit, and it at once occurred to me that

the brown spot must be the satellite itself, and, as I can find no record of a similar previous observation, I venture to forward this note, hoping that others with ampler opportunities will tell us more of a deeply interesting if not unique phenomenon.

Llanelly:
1892 *March* 11.

Notes on the Spectrum of the Great Sun-Spot Group of 1892 *February.* By Prof. K. D. Naegamvala, M.A.

While examining the large spot group, which made its appearance on the Sun's disc early last month, for the widened lines in the region *b* to F, on the 12th of the month, I found that, besides an unusual thickening of the lines both in intensity and number, the F and C lines were reversed at the centres of the two chief nuclei of the group. The absorption was so intense that the lines were frequently obliterated in the nuclei, and I had to displace the nuclei from the slit and observe the widenings in the neighbouring portions of the spot.

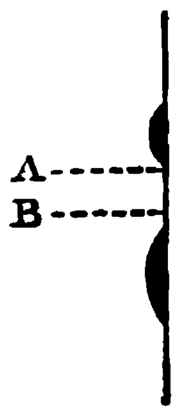
While repeating the observations on the morning of the next day, at about 10.30 Madras mean time (5.10 A.M. G.M.T. nearly), with the slit crossing both the nuclei, it was found that the reversed lines of the day previous had greatly increased in intensity. During observation, the C line gradually extended from one nucleus to another, and was displaced towards the more refrangible side by about its own thickness. The F line was also similarly affected, but with it the displacement was greatest in the space *midway between* the two nuclei. Subsequently, when the slit was placed slightly off the centre of the preceding nucleus (A) with the fine motion in declination, a small *dark* prominence was observed on the F line towards the less refrangible side, a little preceding A, and tipped downwards in the spectroscope towards the spot. On bringing the spot (A) again on the slit it was found that the F line in the spot had assumed a lozenge shape and was also deflected towards the more refrangible side by a distance estimated to be equal to the thickness of the F line. To make myself certain of the existence of the dark prominence, the spectrum was adjusted for the C line, when the black prominence was again observed, but the tip was now deflected away from the spot. That the appearance was not due to any defect or flaw in the instrument was evident from the fact that the appearance was not presented in any other part of the spectrum examined (C to F), except on the two H lines.

Besides the lines C and F, the lines D_1 D_2 D_3 b_1 b_2 b_3 b_4 were found reversed, and on pointing the observing telescope to the region near G it was ascertained to be similarly affected.

The *b* lines, though found reversed, were not observed

bright in the *same* region of either of the two nuclei, and the two centres of the spot had to be slightly shifted in the slit to successively observe the reversals of the four *bs*. The uprushes, therefore, of the elements represented by these lines were evidently of a more restricted character than those of hydrogen and sodium.

D_3 was very bright in both the nuclei, but did not extend from nucleus to nucleus like the hydrogen lines. On the other sides of both the nuclei, however, the helium line extended in continuation of the bright ones, though situated slightly towards the red end. On the side of the preceding nucleus (A) it extended to a distance of about six times the length of the reversed D_3 in the nucleus, and on the side of the nucleus following (B) it was observed to a distance equal to about four times the length of the reversed line in that nucleus. These absorption helium lines were not of uniform thickness and intensity, and they gradually disappeared on the background of the spectrum. The space between A and B was also subsequently found to be crossed by the absorption line of D_3, but there it was much less in intensity than beyond the spot centres. A short while after, the spots were put off the slit by a slight motion in declination, when almost throughout the whole



region of the spot-group the dark D_3 was observed flashing out, rather fuzzy in appearance and broadened as indicated on the less refrangible side, but in regions beyond A and B. At no time did the bright D_3 cross from spot to spot as did the H lines.

Other duties obliged me to postpone observing at about 12.30, Madras mean time, but three hours afterwards (about 10 A.M. G.M.T.), when I resumed observing, the disturbance had almost died away. D_3 was completely absent from both the spots, either as an absorption or emission line, and the only line then positively seen to be reversed was C in nucleus A, while the reversal of F was also suspected. On the other hand, the spectrum of nucleus B was normal in appearance.

On writing to the Director of the Colaba Magnetic Observatory, I was informed that "one of the largest magnetic storms of recent years occurred here (at Bombay) between 10 A.M. (local time ?) of the 13th, and 10 A.M. of the 14th inst. It

continued in moderated intensity for the next twelve hours, and then gradually died away."

The spectroscope employed had a dispersion of three flint prisms of 60° once reversed, with collimator and spectroscope of 1″ aperture, magnifying fifteen diameters. The dispersion obtained showed many more lines than in Angström's Spectre Normal.

The Mahárajah Takhtasingjee (of Bhavnagar) Observatory, College of Science, Poona:
1892 *March* 11.

On the Estimation of Star Magnitudes by Extinction with the Wedge. By Capt. W. de W. Abney, C.B., D.C.L., F.R.S.

Some experiments which I have recently made, and communicated to the Royal Society in a paper by Gen. Festing and myself, Colour Photometry, part III., have a direct bearing on the estimation of star magnitudes by the wedge, and it has seemed advisable to put on record in what way this occurs.

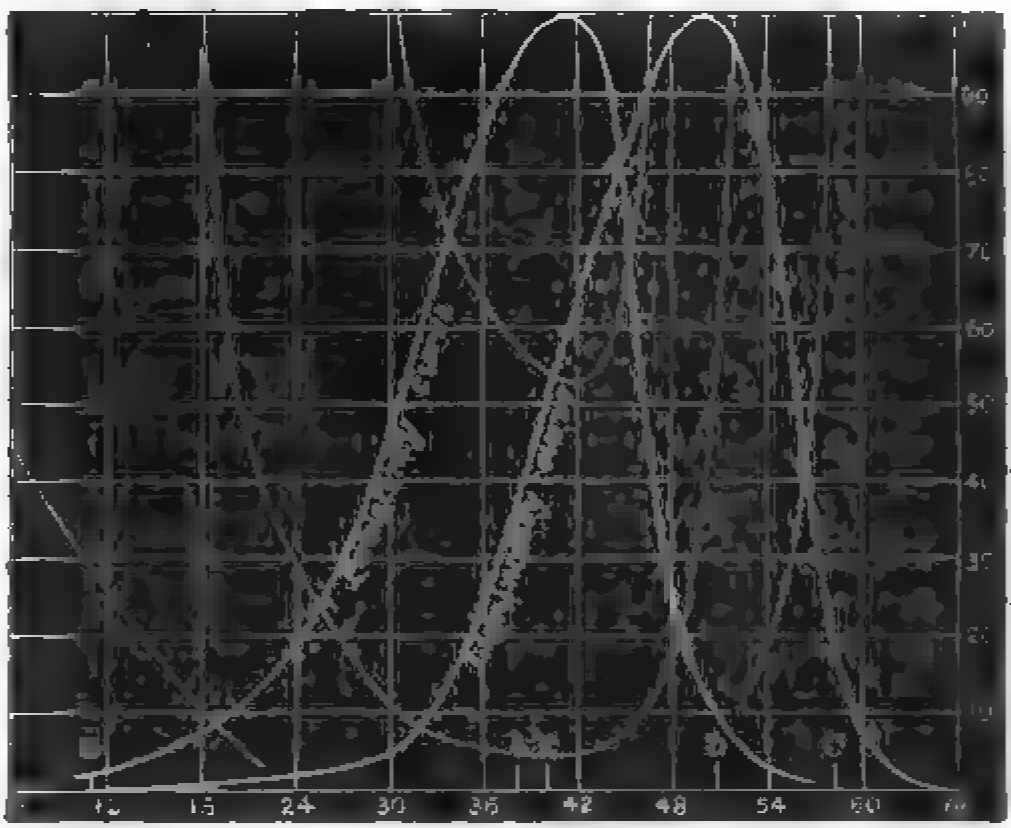
Amongst other matters, the question arose as to the amount by which the intensity of any ray of the spectrum would have to be reduced before it became invisible. Of course the comparative luminosity of the spectrum had to be known at the various parts, and when the absolute luminosity in candle power of any one ray was known, the others could be calculated. In the experiments in question, the spectrum used was that formed by the positive pole of the electric light, and the comparative luminosities were measured, as also the absolute intensity of the light at D coming through a slit placed in the spectrum. This light was spread out into a square patch by a suitable optical arrangement so as to fall on the end of a darkened box, where a black screen with a white disc received it. The light was gradually diminished until the eye which observed through a small aperture in the box could no longer distinguish the white disc. Measures taken in this way showed that if the D light were reduced to $\frac{350}{10,000,000}$ of a standard amyl lamp (which in future for shortness I will call A L) the illumination was so feeble that the white disc could no longer be seen, and no scintilla of light was visible to the eye. The green E light had to be reduced to $\frac{65}{10,000,000}$, the F light to $\frac{150}{10,000,000}$, the G light to $\frac{3,000}{10,000,000}$, whilst the red light at C had only to be reduced to $\frac{110,000}{10,000,000}$ before the screen was invisible. These are the numbers when the D light in the

original spectrum had a luminosity (or brightness) equal to 1 A L, illuminating a screen 1 foot off. If we make the rays of the spectrum throughout equal to 1 A L, these numbers, of course, will be modified. The D light would remain at $\frac{350}{10,000,000}$ A L, since it was originally of the value of 1 A L, but the E light would be $\frac{35}{10,000,000}$ A L, the F light would become $\frac{17}{10,000,000}$ A L, and the G light $\frac{15}{10,000,000}$ A L, while the C light would be $\frac{22,000}{10,000,000}$ A L.

Further, it was found that near F, but on the G side of it, the extinction value of 1 A L became $\frac{15}{10,000,000}$, and remained the same to the extreme violet. It will thus be apparent that to extinguish two lights of equal luminosity, one of C colour and the other of G, the reduction to produce extinction required for the latter is nearly 1,500 times greater than that required for the other. I may remark that a little further than C towards the extreme red, the extinction is the same for every ray when equal luminosities are used.

The Young-Helmholtz theory of colour-vision tells us that there are three fundamental sensations, which are popularly named red, green, and violet, and that at each end of the spectrum but one sensation is excited, viz. at the extreme red, the red sensation, and at the extreme violet, the violet sensation, and that intermediate colours are produced by different degrees of stimulation of the three sensations. The extinction curve of the spectrum offers some confirmation of this theory; for evidently if but one sensation exists at each end of the spectrum when the luminosities of the different rays at these parts are made the same, the extinction of the one sensation will be the same, and would therefore give straight lines in the curve of extinction for equal luminosities, which it does. But we must not forget that the violet sensation is 175 times more persistent than the red, and probably 50 times more than the green. Hence, if we have a colour such as blue-green, which is produced by exciting the violet and green sensations, and probably also slightly the red sensation, when we extinguish this colour it will be the violet sensation which will be far the last to be extinguished. When the green sensation is twenty-five times, and the red sensation 1,500 times more strongly excited than the violet, then all three would be extinguished together. But measures show that if we mix 1,500 parts of pure red with one part of pure violet, the latter is unperceived; and the one part of violet can scarcely have any effect when mixed with twenty-five green. We may take it, therefore, that almost up to the point near D, where the violet sensation ceases,

according to the Young-Helmholtz theory, the sensation that is extinguished is the violet sensation. If, now, we take the reciprocals of the extinction curve of the spectrum, we shall have the amount of violet sensation which exists between the extreme violet and near D. This evidently is the case; for if twice as much violet sensation is excited by one colour as is excited by another, then in order to extinguish the first we must reduce it twice as much as we shall have to reduce the last. This curve of reciprocals we have called the persistency curve. We have thus arrived at the fact that the first sensation to be excited by feeble light is the violet, and that in the electric light spectrum the colour in which it is most present is close to E; in other words, that the maximum of the curve is there. I may mention that in examining two persons who possessed monochromatic vision their measures of luminosity of the spectrum coincided with the persistency curve of my eyes, which, it may be remarked, are normal; and also that the persistency curve of red-blind and green-blind persons are also the same, but that of a violet-blind person is totally different.*



The wedge has therefore so to reduce the light of a star that this violet sensation is not excited; and the last ray which will be extinguished will be the green close to E, supposing the light to be similar in quality to that emitted by the positive pole of the electric arc light.

It must be remembered, however, that we are not dealing

* This being so it is probable that all extinctions made by any one except a violet colour-blind person would be comparable with one another.

with the spectrum when we are extinguishing starlight, but extinguishing all the violet sensation contained in that light.

In a paper in the *Phil. Trans.* on the "Transmission of Solar Light through the Atmosphere," I have shown that the total absorption of light by a medium of varying thickness can be ascertained by measuring the absorption of a single ray which lies close to the maximum of its absorption curve in the spectrum. It follows, therefore, that to scale a wedge for extinguishing of white light, the absorption of E light should be measured. The electric light as used by myself differs very little from sunlight, and any small variation in the quality of the light will not materially shift the position of maximum. The measurement of the absorption of the brightest part of the spectrum, or of the whole of the rays, will not necessarily give the true extinction value of the wedge. If a really black wedge were used, as all rays would be equally reduced, the measurement of the total light transmitted, or that of any ray through different thicknesses of the wedge, would give the coefficient of the wedge for extinction purposes; but if a purplish wedge or an orange wedge were used, it might not do so, supposing that the absorption of E light was different from that of the other rays.

I believe that the wedges used by Professor Pritchard are of a greenish hue, and consequently the place of maximum luminosity of the spectrum seen through it would not differ much from E. I have a wedge myself in which the coefficient of absorption of the total light differs very largely from the coefficient of absorption of the E light. Such a wedge, if graduated in the ordinary way, would give erroneous results.

Another point to be noticed is this, that star magnitudes obtained by extinction should agree better with those obtained by photography than those obtained in the ordinary way by eye estimation. The first would be obtained by an estimation of the E light, the second by that of the light between G and F, and the last by that of the light near D; for it is in these places that the maxima of the curves of extinction, sensitiveness of photographic salt, and luminosity of the spectrum to the eye are respectively situated. A red star would be most frequently of less magnitude to the eye than to the photographic plate, and by extinction it would be between the two. A blue star would be just the reverse, but the extinction magnitude would again probably lie between the two.

Estimations of Magnitude of Nova Aurigæ, made at the Radcliffe Observatory, Oxford. By E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.

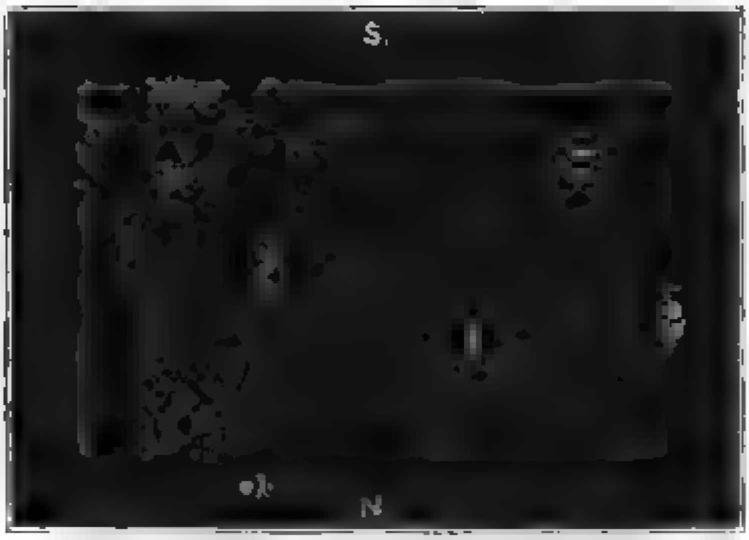
Date.	Observer.	Observed Magnitude of *Nova*.	Comparison stars.	Remarks.
1892.				
Feb. 3	F. B.	4·4	—	Transit-circle observation. No colour to star.
3	E. J. S. and R.	4·5	χ Aurigæ	Observed with Barclay Equatoreal. Star reddish.
5	R.	4·6	...	Transit-circle observation.
13	F. B.	5·1	...	Transit-circle observation.
16	R.	5·7	χ Aurigæ	Naked-eye estimation.
18	F. B.	5·3	...	Transit-circle observation. Star reddish.
22	W.	5·3	...	Straw yellow. Transit-circle observation.
24	R.	6·1	Arg. Z + 30°·898 and 963	Observed with Barclay Equatoreal on February 24, and all succeeding dates.
Mar. 19	E. J. S.	8·8	*v, w, x, k, a,* and Arg. 963	
19	F. B.	9·1	*v, w, x, k,* Arg. Z + 30°·938 and 939	Red colour.
22	W.	9·6	*g, h, i, k*	Not very red, but occasionally a deep red flicker seemed to pass over the image.
22	R.	9·6	*a, h*	
24	R.	10·4	*a, g, i, k*	
24	W.	10·7	*a*	
25	W.	11·7	*a, b, c*	Just discernible through haze.
28	F. B.	13·1	*e, ξ, d, c, j*	Sky very clear.
29	R.	13·0	*b, c, d, ξ*	Very cloudy. Observed in brief intervals of cloud.
30	F. B.	13·7	*e, f, d, p, ξ*	Very brilliant sky. Moon nearly set.
30	W.	14·0	*ξ*	Probably near the limit of the power of the telescope.
31	W.	14·0	*ξ, d*	Not continuously seen.
31	F. B.	14·0	*p, d, ξ*	Sky very clear, but moonlight.

Moonlight has interfered to some extent with any further observations; but, as a matter of fact, although the star has

been looked for on all clear nights up to April 7, it has not been distinctly recognised since March 31.

Observers: E. J. S., Mr. Stone; W., Mr. Wickham; R., Mr. Robinson; F. B., Mr. Bellamy.

The relative positions of many of the comparison stars and *Nova* are roughly indicated in the following chart:—



Nova = R.A.	5h 25m	N.P.D. 59° 38′ (1892·0)
Star *k* = "	5 25	" 59 28 "

The following are the adopted magnitudes of the comparison stars (in the chart) used in determining the brightness of the *Nova*; they are derived from observation. The magnitude of star *k* is *assumed* to be 9·5 (from *Argelander*), and the limit of vision 14·5.

a = 10·2 mag.	*i* = 10·3 mag.	
b = 11·8 "	*j* = 12·3 "	
c = 12·0 "	*k* = 9·5 "	Arg. Z + 30°, No. 924
d = 13·5 "	*v* = 9·7 "	
e = 13·4 "	*w* = 9·7 "	
f = 13·5 "	*x* = 9·7 "	
g = 10·2 "	*p* = 14·3 "	
h = 9·7 "	*ξ* = 13·9 "	

The magnitudes of the remaining comparison stars are taken from *Argelander*, viz.:—

χ Aurigæ	5·0 mag.
Arg. Z + 30°898	6·2 "
Arg. Z + 30·963	6·0 "
Arg. Z + 30·938	8·7 "
Arg. Z + 30·939	9·5 "

The magnitudes of the comparison stars, and therefore of the *Nova* referred to them, are at present only provisional.

Radcliffe Observatory, Oxford:
1892 *April* 8.

The New Star in Auriga. By George Knott, B.A., LL.B.

The following observations of the new star in *Auriga* form a continuation of the series in the March number of the *Monthly Notices*. The magnitudes were either gauged directly by the method of limiting apertures, or estimated by comparison with stars the magnitudes of which had been so gauged:—

		m		m
Mar.	12	7·0	Apr. 1	13·4
	14	7·7	2	13·5
	18	8·9	3	13·5
	19	9·1		
	25	11·6		
	28	12·2		
	30	13·0		
	31	13·3		

As the star decreased in brightness its colour seemed to deepen slightly to a ruddy orange. On March 18 the F line in the spectrum was still bright and well seen, but I felt doubtful as to other lines. I thought it probable that as the light of the new star faded I should find that I had underestimated the magnitude of the 11 mag. star referred to, with measures, in my former paper. This has proved to be the case. From several determinations I find 10·6 as this star's probable magnitude. The star D.M. $+30°\cdot924$ I have observed to be 10·5 mag., a magnitude fainter than the D.M. estimate. This star is preceded 10^s, $3'\!s.$, by a rather brighter star of about 10·3 magnitude.

I give below a list of approximate places for 1892·0 of some small stars in the near neighbourhood of the new star. As most of the stars are faint, the places given are only rough approximations. In the list the new star is marked "var."

Mag.	R.A. h m s	Decl. ° ′
13·3	5 25 0	+30 22·4
var.	25 3	21·8
10·6	25 6	23·0
13·4	25 6	20·1
13·6	25 9	23·1
11·9	25 13	20·0
12·2	25 16	20·1

If the places of the stars in the above list are roughly charted, and compared with the sky, there will, I think, be no difficulty

in their identification. I hope that the magnitudes of the stars will be found to be fairly correct. Unfavourable weather, and the presence of the Moon, have at times made observation difficult.

Knowles Lodge, Cuckfield:
1892 *April* 6.

Anderson's New Star in Auriga. By S. W. Burnham.

My observations of the new star which has recently appeared near 26 *Aurigæ* are confined to micrometrical measures of its position with reference to the faint stars in the field with it. The 36-inch refractor has been used, and I have measured all the stars within a radius of 2′ which could be seen with that aperture. Some moderately bright stars with greater distances have been measured, but without attempting to include all the outlying stars which could be seen.

The following are the measures:—

A and B.

1892·115	81°·6	32″·98	5·7 . . .	14·5	4·30
·118	84·1	33·21	. . .	15·5	6·30
·151	84·7	33·41	. . .	14·5	6·35
1892·14	83·5	33·20		14·8	

A and C.

1892·151	152°·0	49″·54	. . .	15	6·15
·153	153·7	48·57	. . .	15·5	9·10
1892·15	152·8	49·05		15·2	

A and D.

1892·151	170°·8	66″·07	. . .	15	6·10
·153	170·0	66·64	. . .	15	9·15
1892·15	170·4	66·35		15	

A and E.

1892·115	323°·3	74″·44	. . .	11·5	4·35
·118	323·9	74·30	. . .	12	6·35
·151	323·6	74·22	. . .	11·5	6·45
1892·14	323·6	74·24		11·7	

A and F.

1892·112	32°·5	85·24	. . .	10	5·15
·115	32·0	84·70	. . .	10·5	4·35
·118	32·4	85·22	. . .	11	6·35
·151	32·6	85·04	. . .	10	6·35
1892·12	32·4	85·05		10·4	

A and G.

1892·115	138°·5	97″·67	. . .	11·4	4·50
·118	138·8	97·54	. . .	12	6·35
·151	138·4	97·85	. . .	11	6·20
1892·13	138·4	97·69		11·5	

A and H.

1892·115	50°·0	118″·77	. . .	11·5	4·40
·118	50·0	118·23	. . .	13	6·40
·151	49·8	118·74	. . .	11	6·35
1892·13	49·9	118·44		11·8	

A and I.

1892·151	161°·3	154″·76	. . .	11·7	6·30
·153	161·0	154·26	. . .	12	9·00
1892·15	161·1	154·51		11·8	

A and J.

1892·115	21°·8	159′·98	. . .	12·5	4·55
·118	21·9	159·46	. . .	13·5	6·40
·151	22·1	158·90	. . .	12	7·30
1892·13	21·9	159·45		12·7	

A and K.

1892·170	231°·7	170″·40	. . .	13	9·15
·186	231·5	170·87	. . .	13	7·40
1892·18	231·6	170·63		13	

A and L.

1892·115	126°·6	172″·21	. . .	10·5	4·55
·118	126·9	171·14	. . .	10·5	6·45
·151	127·0	171·60	. . .	10·8	6·25
1892·13	126·8	171·65		10·6	

A and M.

1892·118	18°·6	183″·95	. . .	6·45
·151	18·6	183·56	. . .	7·35
1892·13	18·6	183·75		

A and N.

1892·112	115°·9	213″·14	. . .	11	7·40
·115	115·7	212·30	. . .	10·5	4·50
·118	115·8	213·05	. . .	10·5	6·45
·151	115·9	212·68	. . .	10·8	6·30
1892·12	115·8	212·79	. . .	10·7	

E and e.

1892·118	24°·0	13″·44	12	. . .	14	6·50
·151	23·7	13·52	11·5	. . .	12·5	6·45
·153	24·8	13·49	11·8	. . .	13	9·15
1892·14	24·2	13·48	11·8		13·2	

M and m.

1892·115	55°·6	3″·22	13	. . .	13·5	5·10
·118	50·7	3·76	14	. . .	14·5	6·50
·151	51·9	4·32	12·5	. . .	12·5	7·40
·153	56·2	4·17	13·5	. . .	13·8	9·20
1892·13	53·6	3·87	13·2		13·8	

There is no star in Argelander in the place of the new star. The nearest star is D.M. (30) 924, given as 9·5 *m*. This is too distant for the field of the lowest micrometer eye-piece of the large instrument, but I have measured these stars with the 12-inch as follows:—

New Star and D.M. (30°) 924.

1892·112	354°·5	455″·61	7·25
·148	354·4	454·68	6·10
·167	354·4	455·05	8·30
·178	354·5	454·83	6·50
1892·15	354·45	455·04	

The three stars which are nearest the primary, B, C, and D, are faint objects, and none too easy to measure with the large telescope. Most of the more distant stars would be easily seen with a much smaller aperture. Two of these, E and L, have very faint companions, and the latter in particular is troublesome to measure. The bright companion, F, is undoubtedly identical with the 9·5 *m* star referred to by Deichmüller (*A.N.* 3070) as having been seen by Krueger in 1858, and $2^s \cdot 5$ following, and 0′·8 north of the present place of the new star.

During the measures the new star has appeared at all times down to the present a little fainter than 26 *Aurigæ*, and, therefore not brighter than 5·5 *m*. There has been but little change in the magnitude thus far. It may be mentioned in this connection that on November 28 I discovered with the large telescope the duplicity of 26 *Aurigæ* (distance 0″·15), and measured the new pair and the old distant companions on several nights between that date and January 22 (see *Astr. Journ.*, No. 256).

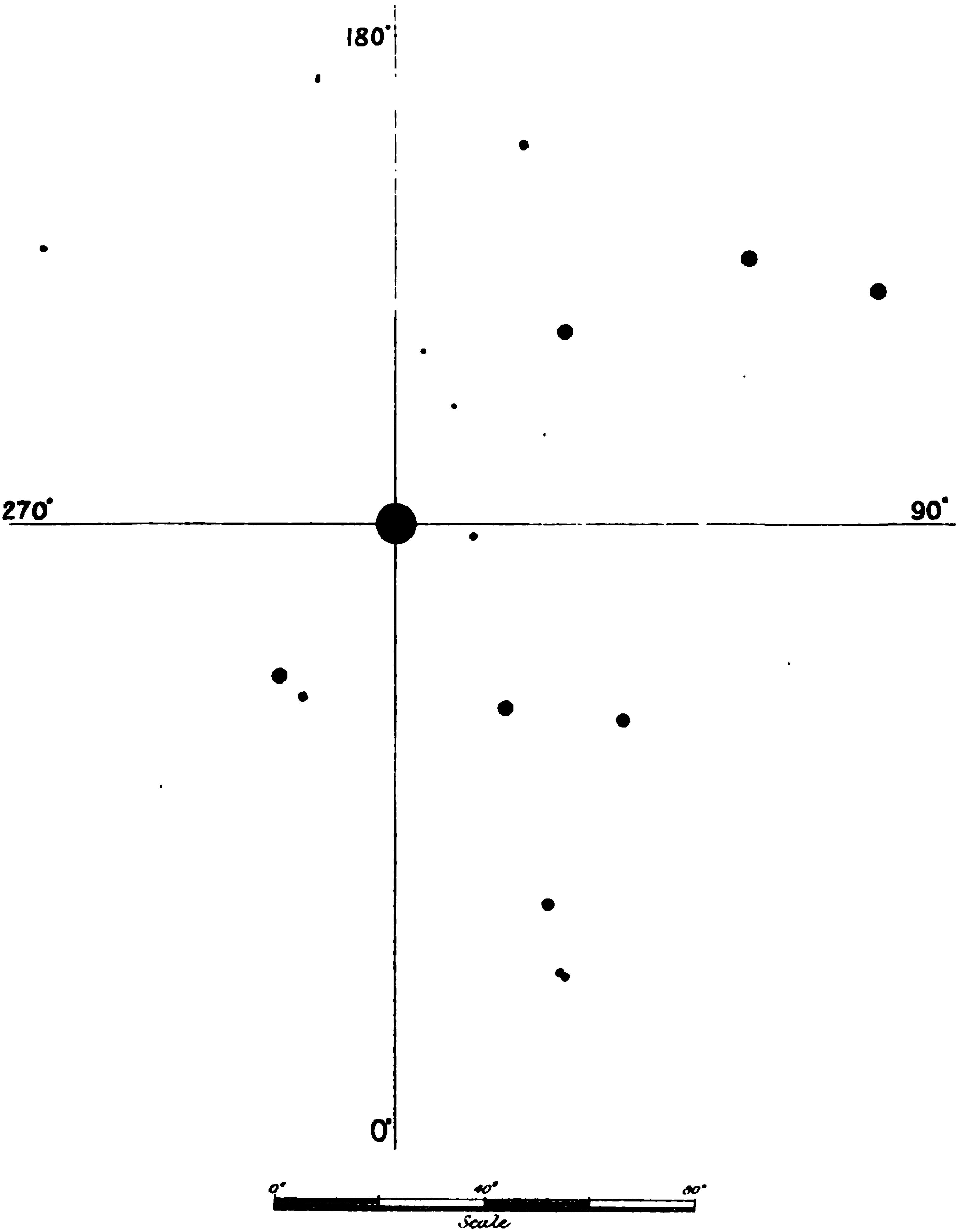
I have compared the new star in declination with D.M. (30°) 913, which precedes the former about 111^s. By three observations the new star is 9″·28 south. In the course of these measures of the various companion stars I noticed that the 8 *m* star, D.M. (30°) 942, which is in the finder following the new star, was a moderately close equal pair, not hitherto known as a double star. This star is *Lalande* 10423. The following measures were made with the 36-inch:—

1892·118	217°·8	0″·83	8·5 . . . 8·5
·151	217·9	0·82	8·5 . . . 8·5
·153	218·0	0·87	8·5 . . . 8·5
1892·13	217·9	0·84	8·5 . . . 8·5

This, of course, would be an easy pair, and will probably have been noticed by other observers.

The accompanying diagram shows the relative positions of the various stars which have been measured from the new star.

Mount Hamilton:
1892 *March* 10.



Stars near the new Star in Auriga,
from measures with the 36 inch telescope.

S.W. Burnham del.

Note.

Since the foregoing was written a very decided change has taken place in the light of this star. My last measure given above was made on March 9, and during the time covered by these observations there had been but little change in the magnitude. The difference from night to night was hardly perceptible, and the diminution did not appear to amount to more than half a magnitude. On March 13 a change was very apparent, and it was then but little, if any, brighter than D.M. (30°) 942, the new double star referred to in the foregoing. Argelander's magnitude of this is 8·0. On the 15th a comparison with D.M. (30°) 913, 924, and 942 gave 8·5 as the magnitude of the new star; on the 16th it was apparently 8·6; on the 20th it was estimated 9·3; and on the 21st, my last examination, it was 9·4. At the present rate of decrease it will soon be comparable with some of the fainter stars I have measured. These stars have a sufficient range of magnitude to be useful for comparison as long as the new star is within the reach of any telescope.

The Double Star, Σ3123. By S. W. Burnham.

There is, perhaps, not another double star in Struve's great work, *Mensuræ Micrometricæ*, which has been measured so rarely as Σ3123. It has been known for more than sixty years, and yet at the most there are but five sets of measures, and two of these are within the last ten years. The scarcity of measures is undoubtedly due to the fact that it is at all times a difficult pair, and beyond the reach of many telescopes used in micrometrical work. There are some observations showing that this star, at various times, was apparently single.

The following are both the positive and the negative results arranged in chronological order:—

1832·20	289°·7	0″·3	W. Struve	3*n*
1840·43	265·±	obl.	O. Struve	2*n*
1841·41	268·7	0·44	O. Struve	1*n*
1841·56	275·3	0·3 ±	Madler	1*n*
1842·78	291·3	0·2 ±	Madler	1*n*
1851·44	Elong. in 231°?		O. Struve	1*n*
1858·44	Single		O. Struve	1*n*
1861·26	Single		O. Struve	1*n*
1862·39	Single		O. Struve	1*n*
1862·95	Single		Dembowski	1*n*
1868·56	Single		O. Struve	1*n*
1881·32	Round		Bigourdan	1*n*
1881·38	221·9	0·32	Burnham	2*n*
1892·14	200·0	0·37	Burnham	3*n*

A careful examination of these observations shows that probably this is a case of slow angular motion, with very little change in the distance. The motion is retrograde, and the distance cannot have been at any time much less than 0″·3. An annual motion of about 1°·5 in position-angle will represent the observations as well as could be expected in a pair of this kind. My measures in 1881 were made with the 15½-inch refractor of the Washburn Observatory, with which this pair was well seen. The last measures were made here with the 36-inch. With the larger telescope, of course, such a pair is very easy under any suitable conditions, and the observations should represent the relations of the components very accurately. The two stars are sensibly equal in magnitude, but there is hardly any doubt about the quadrant, because the angular change between 1832 and 1841, and between 1881 and 1892, would seem to show that there could not have been an occultation during the intervening time when it was not seen double, nor any considerable diminution in the distance. Evidently this is not so interesting a binary as heretofore supposed, since the angular motion in sixty years is only about 90°.

The place of this star (1880) is:—

$$\left.\begin{array}{ll}\text{R. A.} & 12^{h}\ 0^{m}\ 0^{s} \\ \text{Decl.} & +69^{\circ}\ 22'\end{array}\right\}$$

It is desirable that this pair should be carefully measured every few years.

Mount Hamilton:
March 10.

A New Binary Star, β 581. By S. W. Burnham.

This fine triple star was discovered in 1878 with the 18½-inch refractor of the Dearborn Observatory. As the close pair was 0″·4 in distance, it was readily measurable with that instrument, and with a moderately close third star it was an interesting object on the telescope, visually at least. About the same time it was measured by Dembowski, and a few years later by Engelmann, so that we have good positions for the components at that time. I have recently looked it up, and made a set of measures with the 36-inch refractor of this observatory. Since these last measures were made I have received from Schiaparelli two sets of measures which fill an important place in the intervening period.

The following are all the measures of both components to this time:—

A and B.

1878·15	176°·9	0″·40	8·0	. . .	8·0	β 2_n
1878·22	180·3	0·40	8·7	. . .	8·7	Δ 1_n
1883·37	205·2	0·30		. . .		En 5_n
1889·23	249·8	0·4		. . .		Sp 4_n
1890·21	253·7	0·5		. . .		Sp 4_n
1891·97	259·4	0·46	8·5	. . .	8·6	β 4_n

A B and C.

1878·13	185°·3	4″·76	. . .	10·5	β 3_n
1878·22	184·3	4·76	. . .	11·0	Δ 1_n
1891·97	192·7	4·60	. . .	11·5	β 4_n

Some of the angles of the close pair are reversed, but I have placed them all on the same side, since this gives nearly uniform motion during the whole time. As there is no material change in the distance, there can be no doubt that this is the proper disposition of the angles, making the total motion during this time 82° instead of 262°. The components are so nearly equal that the 36-inch shows but little difference in magnitude.

There is a remarkable similarity between this triple system and that of *ζ Cancri*. The close pair of the latter has a period of about 58 years. In this star the motion of AB since 1878 has been at the rate of 6° per year. On the assumption of uniform motion, this would give almost exactly the same periodic time. The third star, C, is about the same distance from AB in each case. In *ζ Cancri* the annual motion is about half a degree in a retrograde direction; while in β 581 the movement is direct, and about the same in amount. Of course, the latter is a much more difficult triple than *ζ Cancri*, and will require a much larger aperture.

This star is Lalande 15743, and the place (1880) is:—

$$\left.\begin{array}{l}\text{R.A. } 7^h\ 57^m\ 44^s \\ \text{Decl.} + 12^\circ\ 38'\end{array}\right\}$$

The triple, β 582, is 22^s following, and 13′ *s*. As a wide pair (20″) this is Σ 1179. On the same night, when the other triple was discovered, I found that the smaller component of Struve's pair was also double. The third star is nearly 4″ from B in the direction of 57°. The distance of the wide pair has increased a little more than 2″ since the measures of Struve in 1829. This is probably due to proper motion. There has been but little, if any, change in the new star since 1878.

Observations of Nebulæ with the 36-inch Refractor of the Lick Observatory. By S. W. Burnham.

The observations of nebulæ which follow were all made with the 36-inch equatoreal, and substantially all of them in the months of September and October, 1891. Most of the objects were selected from the General Catalogue, because of some uncertainty in the descriptions of the nebulæ, or doubt concerning their places or actual existence. These observations were dovetailed in with the regular work, so as not to interfere materially with the more important micrometer measures of close double stars; and, of course, the best nights were not used for this purpose, but the conditions were good enough for work of this character.

I have relied upon Dreyer's General Catalogue for the places and the general descriptions. The numbers used in all cases refer to this work. I have referred the places derived from the measures to 1860, the epoch of the General Catalogue. It would certainly be a great convenience to observers if the places of all newly discovered nebulæ were given in the same way. There is nothing gained by carrying the places forward to any current date. So far as setting on these objects is concerned, one time is as good as another, and since we have a general catalogue there is every reason for adhering to that epoch. For the general purposes of a catalogue approximate places are sufficient, and the nearest minute of R.A. is close enough; but it is very desirable that as many nebulæ as possible should be carefully observed with the micrometer, and measured directly (angle and distance) from some convenient star for the detection of proper motion. It is in this way only that change of this character is likely to be discovered. The R.A. and Decl. may have the highest accuracy, but there is no way of easily ascertaining whether there has been any movement. If we have the angle and distance from a star in the field, the micrometer wires can be placed in a couple of minutes so as to show whether or not it is necessary to do anything more. Of course, for this purpose, it is a matter of no consequence that the comparison star is not found in any catalogue.

In the course of these observations some new nebulæ have been found in the vicinity of the catalogue nebulæ under examination. These are referred to in the proper places. No attempt has been made to find new objects, and in my regular work with micrometer the faint nebulæ which are occasionally met with are, as a rule, only saved when they are near enough to some prominent star for direct measures.

No. 607.

$$\left.\begin{array}{l}\text{R.A. } 1^h\ 27^m\ 16^s \\ \text{Decl.} -8^\circ\ 7'\cdot 8\end{array}\right\}$$

This is one of D'Arrest's nebulæ, given in Dreyer with the note, " 11 *m* star nebulous ? " and it is further stated, " No nebulosity seen by Schönfeld, but Auwers saw it (*Kön. Beob.* 226)."

This should be, from the catalogue place, a little preceding an $8\frac{1}{2}$ *m* star. There is certainly nothing in this place. I found a rather conspicuous nebula a short distance following, which was subsequently identified as Dreyer 615. This has a bright central nucleus, with long nebulous wisps extending on each side in the direction of 160°—340°. These streaks extend roughly about 33″ on either side of the nucleus. This nebula is 20^s following, and 126″ north of the $8\frac{1}{2}$ *m* star mentioned above. The star is S.D. (8°) 273. Applying these differences to the S.D. place of the star, we have for the place of the nebula (1860):—

$$\left.\begin{array}{l}\text{R.A. } 1^h\ 28^m\ 26^s \\ \text{Decl.} -8^\circ\ 3'\cdot 3\end{array}\right\}$$

This agrees substantially with Herschel's place. A few nights later (1891·753) this region was very carefully examined again. There was nothing in the catalogue place of Dreyer 607 in the least suggestive of nebulosity. There is no doubt that No. 615 is the object which has been seen in looking for the other, and that it is one of the many instances of mistaken identity.

No. 618.

$$\left.\begin{array}{l}\text{R.A. } 1^h\ 28^m\ 20^s \\ \text{Decl.} +32^\circ\ 40'\cdot 6\end{array}\right\}$$

Dreyer has the note, " Never found at Birr, nor by D'Arrest. Schönfeld has two observations, very faint, excessively small = 13 *m* star, place agreeing with Herschel. Query: only a faint star."

The catalogue place was carefully examined (1891·747) without finding the least trace of any nebulous object. I found two faint nebulæ a short distance north, and compared them with the 8·2 *m* star, D.M. (32°) 281. The first is $1^m\ 21^s$ preceding, and 22″·4 south of that star; and the second is 58^s preceding, and 68″·4 north of the same star. These objects are respectively Dreyer 608 and 614. The differences applied to the D.M. place of the comparison star give for the nebulæ (1860) :—

$$\text{Dr. 608}\quad \left.\begin{array}{l}\text{R.A. } 1^h\ 27^m\ 23^s \\ \text{Decl.} +32^\circ\ 56'\cdot 1\end{array}\right\}$$

$$\text{Dr. 614}\quad \left.\begin{array}{l}\text{R.A. } 1^h\ 27^m\ 46^s \\ \text{Decl.} +32^\circ\ 57'\cdot 6\end{array}\right\}$$

The Right Ascensions are each 7^s less than the catalogue places, while the declinations are substantially the same. On a

subsequent night this region was carefully gone over with the same result so far as No. 618 is concerned. There is certainly nothing in the catalogue place, and this object has probably been confounded with one of those mentioned above. This is also the case with No. 627. The place of this is a little following the two measured, and in about the same declination. The place of this was doubtful to Herschel, who says: "The R.A. conjectural, and P.D. liable to some error." It is safe to say that Nos. 618 and 627 do not exist, and that the observations credited to them really belong to Nos. 608 and 614.

No. 707.

$$\left.\begin{array}{l}\text{R.A. } 1^h\ 44^m\ 31^s \\ \text{Decl.} -9^\circ\ 12'{\cdot}0\end{array}\right\}$$

This nebula was discovered by Tempel, and was described by him "very faint; faint star in centre." I looked this up (1891·766) more particularly to see whether it belonged to the planetary class, the possibility of that being suggested by the central star mentioned. It does not belong to that order of nebulæ. There are really two stars, one much fainter than the other, with a faint, diffused nebulous light surrounding them. I called the magnitudes 13·5 and 15·5. The latter would, of course, be entirely beyond the reach of the instrument used by Tempel. A rough setting of the wires gave for the angle between these stars 302°, and for the distance between them 10″·4.

The nebula was compared with a small star preceding, S.D. (9°) 345. This is 9·8 *m* in S.D. The nebula is 45^s following, and 26″·8 north. Applying these differences to the S.D. place of the star gives for the nebula (1860):

$$\left.\begin{array}{l}\text{R.A. } 1^h\ 44^m\ 31^s \\ \text{Decl.} -9^\circ\ 12'{\cdot}8\end{array}\right\}$$

In identifying and fixing the place of this nebula I found a new one in the immediate vicinity, which was measured directly from the same comparison star used for the other.

S.D. (9°) 345, *and new nebula.*

1891·766 P = 260°·9 D = 221″·3

These measures give for the place of the new nebula (1860)

$$\left.\begin{array}{l}\text{R.A. } 1^h\ 43^m\ 31^s \\ \text{Decl.} -9^\circ\ 13'{\cdot}4\end{array}\right\}$$

This is fainter than the other, though easily enough seen.

No. 736.

$$\left.\begin{array}{l}\text{R.A. } 1^h\ 48^m\ 35^s \\ \text{Decl.} +32^\circ\ 21'{\cdot}1\end{array}\right\}$$

There is a cluster of faint nebulæ in this place. The catalogue places of the others are:—

No.	R.A. h m s	Decl. ° ′	
737	1 48 36	32 21·6	Rosse
738	1 48 38	32 22·0	Rosse
739	1 48 47	32 28·0	Copeland
740	1 48 48	32 19·7	Rosse

No. 737 is described: "Stellar nebula (? faint star) 27″ north of *h* 169 (No. 736)." The 36-inch shows that this not a nebula, but a faint star, 13·5 *m.* Two measures of this from *h* 169 were made with the Parsonstown reflector. Evidently they are only very rough settings, as the difference in the distances is much too large for careful measures. These observations and my own are as follows:—

	°	″
1850·775	10·4	27
1874·022	11·9	35·1
1891·766	9·8	32·31

The 36-inch shows a very faint star, which I have called 15·5 magnitude, between and a little preceding the line joining the two objects measured above (Nos. 736 and 737). A single setting of the wires makes the new star 22″·0 from No. 736 in the direction of 7°·6. Of course a star of this magnitude is a faint object with the largest apertures. There is no trace of any nebulosity about either star. There is no doubt that No. 737 should be rejected as a nebula from any future general catalogue.

The position of No. 738 was also measured from *h* 169 at Parsonstown. This and the later measures are as follows:—

No. 736 *and No.* 738.

	°	″		
1850·775	43·7	75	Rosse	1*n*
1891·766	47·3	82·34	β	1*n*

Dreyer 740 is not far from a 9·4 *m* star, and I have measured the angle and distance directly, as was done at Parsonstown:—

D.M. (32°) 348 *and No.* 740.

	°	″		
1874·022	278·2	74·6	Rosse	1*n*
1891·766	279·3	74·11	β	1*n*

My measures applied to the D.M. place of the comparison star give for the place of the nebula (1860):—

$$\left.\begin{array}{l}\text{R.A. } 1^h\ 48^m\ 48^s \\ \text{Decl.} + 32^\circ\ 18'{\cdot}5\end{array}\right\}$$

There are some other faint nebulæ in the vicinity (Nos. 733, 750, 751, 760, and 761), but I did not examine these.

No. 874.

R.A. $2^h\ 9^m\ 43^s$
Decl. $-23°\ 50'.5$

This was discovered by Müller with the 26-inch refractor of the McCormick Observatory. The description is, "Excessively faint, pretty small, extended 170° (? double star), 10 *m* star *n.p.*"

I could not find any nebula in or near this place. The vicinity was carefully swept over, without coming across any nebulous or suspicious object. The assigned place is well marked, as the nebula should be about 9′ south of an 8½ *m* star (Gould 2301). This star, by the way, is double (new), 160°: 1″.2 : 8.7 ... 10 estimated. It is safe to say that this nebula has no real existence. Probably a faint star was seen. The large telescope shows many near this place.

No 878 is south following the place of the other. I compared this with a neighbouring star (Gould 2284), which is $2^m\ 19^s.5$ preceding, and 43″.6 south of the nebula. This gives for the nebula (1860):—

R.A. $2^h\ 11^m\ 30^s$
Decl. $-24°\ 1'.9$

This was discovered by Leavenworth with the McCormick telescope. The R.A. from my observations is 40^s greater than that given in the General Catalogue. The declinations are nearly the same. This is a faint globular nebula, and comparatively easy.

No. 905.

R.A. $2^h\ 16^m\ 26^s$
Decl. $-9°\ 22'.2$

This is also one of Leavenworth's discoveries with the McCormick 26-inch. In or very near the place I found what seemed to be an exceedingly faint patch of nebulous light. The seeing was not good enough to be certain that it was not due to faint stars, but it is probably a nebula. This is a very blank region for stars, and as there was no convenient comparison star, the place of the object was not taken.

No. 942.

R.A. $2^h\ 21^m\ 30^s$
Decl. $-11°\ 27'.2$

No. 943 has exactly the same R.A., and is 1′.0 less in Decl., and given with the description, "Very faint, round; neb. double

star?" These were discovered by Müller at the McCormick Observatory. These objects should be very near a faint S.D.M. star, 9·4 *m*. The R.A. of that star is but 4^s more than that given for the nebulæ, and its Decl. $-11°$ 24′·8, and therefore the nebulæ should be about 1′ or 2′ south. There are two faint stars nearly in this place, but they have no nebulous appearance, and are certainly nothing but faint stars. A little following this place there is a small faint nebula (*a*), and still farther following a double nebula (*b c*). Both components of the latter have faint nuclei. The brightest of the two is *b*; and *a* is considerably fainter than either. I have compared these with the star mentioned above, S.D. (11°) 466, with the following result:

Neb. (*a*) *s* of star 187″·5 and 26^s *f*
Neb. (*b*) *s* of star 201·6 and 49 *f*

The double nebula was measured directly:

Neb. (*b*) *and Neb.* (*c*).

1891·769	P = 340°·3	D = 33″·90

These observations give the following places for these nebulæ for 1860:

	h m s	° ′
Neb. (*a*)	2 22 0·5	−11 27·9
Neb. (*b*)	2 22 23·5	−11 28·1
Neb. (*c*)	2 22 22·7	−11 27·6

There is but little doubt that the two nebulæ discovered by Müller are *b* and *c* of the foregoing observations. The other, *a*, is fainter, and might have been easily overlooked, and is certainly new.

There is a star $8\frac{1}{2}^m$ 13^s following, and 9′·4 north of the comparison star previously referred to, which is a new double star. As the components are quite unequal, it will not be readily seen with most instruments. This star is S.D. (11°) 467 (=Weisse II. 356=Santini 197). The star catalogues differ some in the declination. My measures of the companion are as follows:

1891·769	250°·9	4″·02	8·2 . . . 13

Two other nebulæ were found north preceding the double star; subsequently identified as Nos. 945 and 948 of Dreyer. The nearest was measured from the double star, and then the two nebulæ with reference to each other, with the following results:

Weisse II. 467 *and No.* 945.

1891·769	P = 334°·6	D = 277″·5

No. 945 *and No.* 948.

1891·769	P = 50°·6	D = 152″·4

Using the Weisse place of the comparison star, these observations give for the nebulæ (1860) the following:

	R.A. h m s	Decl. ° ′
No. 945	2 21 39	−11 11·7
No. 948	2 21 47	−11 10·1

In the General Catalogue there is a difference of 24^s in the right ascensions, and $1'·6$ in the declinations. The first was discovered by Herschel I., and the other by Swift at the Warner Observatory.

No. 955.

R.A. $2^h\ 23^m\ 26^s$
Decl. $-1°\ 44'·0$

This nebula, which was discovered by Herschel I., has not been found at times by some observers, and variability has been suggested as an explanation. Dreyer has this note:—"In *Monthly Notices*, xxxviii.; 104, Winnecke drew attention to the remarkable circumstance that this nebula was invisible to Schönfeld in December 1861, and to Vogel in November 1865, while it was easily seen by D'Arrest, Schönfeld, and Winnecke in 1856, 1863, 1864, 1868, and 1867. Possibly the brightness of this object is variable. In November 1887 it was fully of the second class."

I found this (1891·747) in the proper place without difficulty. It is a long, narrow nebula, in a general way similar to Dreyer 607, which was examined a few minutes before. It has a bright central condensation, with nebulous wings on either side in the direction of 15°–195°. A setting of the wires gave for the extreme length 75″. On the whole it is rather a curious object, and should be easily found and seen. It is probable that the failures to find it, mentioned above, were due to unfavourable atmospheric conditions. This would fully explain the observations with the moderate apertures which were probably used.

No. 988.

R.A. $2^h\ 28^m\ 34^s$
Decl. $-9°\ 57'·9$

This was discovered by Stone at the McCormick Observatory, and is described in Dreyer as a "nebulous star 7·5 *m.*" I could see (1891·766) nothing suggestive of any nebulosity about this star, or any peculiarity in its appearance. Other stars of about the same magnitude in the vicinity were looked at, and I could not detect any appearance in the star in question which was not common to the others. It was examined on the same occasion by Barnard, and he came to the same conclusion. It is

therefore safe to say that the suspected nebulosity about this star is a mistake.

No. 1059.

R.A. $2^h\ 34^m\ 45^s$
Decl. $+17^\circ\ 24'\cdot5$

This is one of Herschel's nebulæ, "excessively faint, hardly sure." Dreyer says, "Not found by D'Arrest on a very clear night." I examined this region very carefully, and am satisfied that there is nothing in the catalogue place. About 1^m preceding this place, and 12′ south I found a very faint nebula. This would be estimated as perhaps 14 magnitude. It is about 30″ or 40″ in diameter, with a gradual brightening towards the middle. It is impossible to say with certainty whether this is the Herschel object, but it is not improbable from the description. It is not otherwise in the General Catalogue.

This was compared with a 7·8 *m* star, D.M. (17°) 419 (=Weisse II. 820). The nebula is 183″·9 north of this star, and 37^s preceding, giving for its place (1860):

R.A. $2^h\ 33^m\ 37^s$
Decl. $+17^\circ\ 12'\cdot7$

There is a small star near the catalogue place of Herschel's nebula, D.M. (17°) 422, which is a new double star. I did not measure it, but estimated, 160° : 1″ : 9·5 . . . 10·5.

No. 1186.

R.A. $2^h\ 56^m\ 20^s$
Decl. $+42^\circ\ 16'\cdot5$

This was discovered by the first Herschel (=II. 502=*h*281). Dreyer has the following note:—"Twice looked for by Lord Rosse, but not found; often searched for in vain by D'Arrest. H. calls it 'a pretty bright star with two faint branches'; he has 'a star 14 *m*, with some kind of nebulous appendage.'"

This was readily found (1891·747) in the proper place. It is a 10 *m* star involved in a faint, elongated nebula. The conditions at this time were not very good, but the nebula appeared to be at least 2′ or 3′ in the longest direction. It precedes an 8·8 *m* star, D.M. (42°) 697, by 44^s, and is 274″ south. From the D.M. place of the star we have for the nebula (1860):

R.A. $2^h\ 56^m\ 18^s$
Decl. $+42^\circ\ 17'\cdot7$

No. 1363.

R.A. $3^h\ 28^m\ 6^s$
Decl. $-10^\circ\ 18'\cdot8$

This nebula was found by me with the 18½-inch at Chicago in 1877. A companion nebula, No. 1364, was discovered subsequently by Müller with the McCormick 26-inch. The first was measured by me at the time of discovery from the 6½ *m* star, L 6634. The difference between the two distances is doubtless due to the fact that this is a large and generally round mass of diffused nebulosity without any central brightness for the accurate placing of the wires. The nebula as a whole is bright enough to be easily seen with the large star in the field. The measures are as follows:—

L 6634 and No. 1363.

1877·997	P = 62°·1	D = 206″·7
1891·845	60·8	203·4

No. 1363 and No. 1364.

1891·845	84°·0	136″·5

Swift ix. 13.

In *Monthly Notices* for December 1891 Dreyer has called attention to a nebula discovered by Swift (*Ast. Nach.* 3004) since the publication of the General Catalogue which may possibly be variable when all the observations, negative and positive, are considered. Swift was unable to find it again, and suggested that it might prove to be a comet. Herschel II. had recorded an object in this place, but it was rejected in his General Catalogue as being identical with a nebula a short distance preceding, discovered by Herschel I. It appears also to have been seen with the Rosse reflector at times, and invisible at other times. For details concerning these observations reference is made to the paper in *Monthly Notices* previously referred to.

I examined (January 28) the several nebulæ in this region, No. 1397 (=III, 569), No. 1417 (=II. 455=*h*306), No. 1418 (=II. 456=*h*307), and No. 1424 (Rosse), with the following result: All of these objects were readily found as given in Dreyer's Catalogue. Swift's nebula is in the place given by him, in line with Nos. 1417 and 1418. It is much fainter than No. 1418, the faintest of the Herschel nebulæ mentioned above, and has but half or two-thirds of the light of No. 1424. I compared it with the 8 *m* star north following (Lalande 6870). The nebula is 72ˢ preceding that star, and 223″ south. We have for the place of this object (1860) the following:

	h m s	° ′
h 305	3 34 32·5	−5 7 ±
Swift	3 34 37	−5 8·0
Burnham	3 34 34	−5 7·0

It follows, therefore, that Swift's nebula is really identical with the rejected *h*305.

There is no catalogue star near enough for direct measurement. There is a 12 *m* star nearly following, which I have measured from the nebula as follows:—

Neb. and star P = 92°·8 D = 155″·0

There is a fainter star much nearer the nebula in the direction of about 300°, and distance, perhaps, 20″ or 30″ With reference to the question of change, it can only be said that the evidence of change does not appear to be entitled to much weight, and the probabilities are that this object has been missed simply because the atmospheric conditions were not sufficiently favourable. The observer is much more liable to overlook differences of this kind when using the low powers ordinarily employed in work of this character. With powers of 400 or 500 and upwards used in making double-star measures, the difference in regard to illumination and definition on different nights is very apparent, and it is on only the very best nights that negative results have any value or significance. In double-star work it is almost a nightly occurrence with any telescope, large or small, that the instrument is pointed to stars which cannot be seen double on that occasion. In my experience this has happened thousands of times, but I have yet to find the first double star where these failures even suggested any variation in the light of either component. It would be very interesting to find a variable nebula, and this object should certainly be watched for a while to see whether there is any change in its light. Dreyer has pointed out that while this nebula was not seen on various occasions, it was only specially looked for in 1877 and 1890. It is easy to see how it might be overlooked under certain conditions, even with a pretty large instrument. In this connection I should say that the night on which my observations were made was much too poor to do any kind of double-star work, even on the easiest pairs, and therefore this nebula would appear fainter than it really is, but this would not affect the comparison with the other nebulæ in the vicinity.

Barnard.

$$\left.\begin{array}{l}\text{R.A. } 3^{h}\ 38^{m}\ 34^{s}\\ \text{Decl.} + 34°\ 37'{\cdot}6\end{array}\right\}$$

This planetary nebula was discovered by Barnard with the 36-inch telescope of the Lick Observatory in December 1890, while examining the region near Zona's Comet (*Ast. Nach.* 3017). I have examined this on three different nights with the same instrument. It is a beautiful object, and has all the characteristics of the regular planetary nebulæ, with the single exception of the central star. On one occasion I suspected the existence of a faint star or nuclus, but could not be certain of it at that time or later. There are two small stars near it, as referred to in *Ast. Nach.* 3017. The nearest I have measured from

the nebula, and have also compared the latter with the 9 *m* star, D.M. (34°) 732.

Nebula and Companion Star.

1891·689	P = 288°·4	D = 21″·79 . . .	13 *m*
·692	287·8	21·78 . . .	13 *n*
1891·69	288·1	21·78	13

The other star, which is fainter, 14·5 *m*, is 33″ from the nebula in the direction of 347°.

Nebula and D.M. (34°) 732.

1891·689	P = 119°·6	D = 204″·5
·692	119·5	203·7
1891·69	119·5	204·1

The same comparison star was used by Barnard, who measured the difference of R.A. and Decl. directly. Reducing my angle and distance to the same terms, the results are:

1890·94	Diff. R.A. = 14ˢ·4	Dif. Decl. = 102″·0 B 1 *n*
1891·69	14·4	100·7 β 2 *n*

The nebula is slightly elliptical in a north and south direction. Measures of the diameter in the direction of 180°, using a power of 1000, gave the following:—

1891·671	10″·9
·689	9·1
1891·68	10·0

The place of this nebula for 1860, given above, is derived from the D.M. place of the comparison star and the measured differences.

No. 1458.

R.A. $3^h\ 40^m\ 40^s$ }
Decl. − 18° 40′·7 }

This is from the Catalogue of nebulæ discovered by Leavenworth at the McCormick Observatory. The description in Dreyer is, "Very faint; very small; round; planetary? nebula?" This region was carefully swept over, and the only thing found was a bright, globular nebula about 2^m preceding the place given for No. 1458. I had overlooked this object in the General Catalogue, and was not aware that it was No. 1440,

and therefore fixed its position by comparing it with O. Arg. S. 2493. The nebula follows that star 29^s, and is $91''\cdot1$ north. This gives for the nebula (1860):

$$\left.\begin{array}{l}\text{R.A. } 3^h\ 38^m\ 43^s \\ \text{Decl.}-18^\circ\ 42'\cdot6\end{array}\right\}$$

This is almost exactly identical with the place in Dreyer. It is hardly possible that I should have missed No. 1458 if any such object really existed. The other object may have been observed under conditions which made it appear much fainter than it really is.

No. 1555.

$$\left.\begin{array}{l}\text{R.A. } 4^h\ 13^m\ 48^s \\ \text{Decl.}+19^\circ\ 11'\cdot2\end{array}\right\}$$

This is Hind's supposed variable nebula. I examined this very carefully in 1890 (*Monthly Notices R.A.S.*, December 1890), and was familiar with its appearance in the large refractor. It was again looked at several times in September and October 1891. At first it was thought to be a little brighter than in 1890, but subsequent examinations made this doubtful. It was also looked at with the 12-inch in 1890 and 1891, and there was no apparent change in the interval. Any variation would perhaps be more easily detected with this instrument than with the larger aperture. It remains to be seen whether there is any change after all in this object.

About 20′ north of this is the so-called variable, *U Tauri*. This is a double star, first noted as such by Knott. I have made the following measures:—

	°	″		
1891·772	203·6	3·25	9·3 . . .	9·4
·804	204·1	3·03	9·0 . . .	9·2
·810	203·7	3·08	9·0 . . .	9·1
1891·79	203·8	3·12	9·1 . . .	9·2

The only other measures with which I am acquainted are:

1868·01	202°·1	3″·10	9·9 . . .	9·9	Knott 2n

Of course very little, if any, change would be expected in a pair of this kind. The variability of this star does not seem to have been satisfactorily shown. On the whole, it is doubtful if there has been any change in the magnitude.

Nos. 1721, 1725, and 1728.

These three nebulæ, all in the same field, were discovered by Barnard in 1886, at Nashville, with a 6-inch refractor (*Sid.*

Mess., January 1886, and *A.N.* 2755). The places in Dreyer are as follows:—

	h m s	° ′
No. 1721	4 52 40	−11 20·6
No. 1725	4 52 55	−11 20·9
No. 1728	4 53 5	−11 20·6

They were subsequently discovered independently by Swift, and given in his *Third Catalogue*. The places in Dreyer are taken from this list. There are faint objects in the 36-inch. They are very much alike generally, but the preceding one is perhaps a little the brightest. The following one is extended in the direction of about 190°. All are considerably brighter in the middle. No. 1723 (Tempel), a short distance north of this group, is much like the others, but a little brighter. It is within a small triangle of stars, two of which are in the S.D. as 9 *m*, and the other is about 10 *m*.

I have measured the relative positions of Barnard's nebulæ (1891·845) as follows:—

1721 and 1725	P = 121°·4	D = 94″·1
1725 and 1728	61·6	78·3

From these measures, 1725 follows 1721 $5^s·4$, and is 49″·0 south; and 1728 follows 1725 $4^s·7$, and is 37″·2 north. The first of these I compared with an 8·4 *m* star preceding (L 9349). The nebula is 1^m 52^s following, and 90″·0 north. Applying these differences to the position of the star, we have the following as the places of the nebulæ for 1860:—

	h m s	° ′
No. 1721	4 52 41	−11 19·9
No. 1725	4 52 46	−11 20·7
No. 1728	4 52 51	−11 20·1

No. 1788.

R.A. 4^h 59^m 57^s }
Decl. −3° 32′·7 }

This is one of the discoveries of the first Herschel (V 32). The description in Dreyer is "B, c L, R, b M, ** 15. * 10, 1½′ 318°, inv. in the nebulosity." The large telescope shows that the brightest part of the nebulosity is around a star 11·5 *m* centrally placed, but it extends to the star referred to by Herschel. This star is S.D. (3°) 1013, where it is called 9·5 *m*. There is no star near the central star, and I do not know what is meant by the reference in the description given above. It would seem to refer to a triangle of 15 *m* stars within the nebula. I have measured the distance and angle of the 11·5 *m* star from the 9·5 *m*:

1891·845	P = 137°·4	D = 99″·07

Between these two there are two faint stars, forming a wide pair, perhaps 6″ or 8″ apart, about one-third of the distance from the 11·5 star towards the other. There is also another faint star a little following the middle of the line joining the same stars.

Barnard.

R.A. $5^h\ 14^m 33^s$
Decl. $+3°\ 20'·7$

This double nebula was discovered by Barnard in 1888 with the 12-inch telescope of the Lick Observatory. It is 55^s preceding, and 4′ south of the wide double star 23 *Orionis* (Σ 696). The two nebulæ with a 10½ *m* star form a nearly equilateral triangle. Calling the nebulæ A and B in order of R.A., I have measured them with reference to each other, and also from the small star:

A and B.

1891·854	P = 115°·2	D = 36″·32
·893	114·5	36·03
1891·87	114·8	36·17

10½ *m Star and A.*

1891·854	246°·3	30″·42
·893	247·0	29·55
1891·87	246·6	29·98

10½ *m Star and B.*

1891·854	169°·8	25″·91
·893	169·5	24·83
1891·87	169·6	25·37

The preceding one of the two is the brightest, and is a little larger than the other. They are faint objects even in the large telescope, and without any well-defined nucleus. The place given above is for A, and obtained from measures by Barnard of its position with reference to D.M. (3°) 864.

In sweeping for these objects I found another nebula in the immediate vicinity which is new. This is similar in appearance to the others, but one or two magnitudes fainter. The position of this was measured from a 9 *m* star as follows :—

D.M. (3°) 863 *and Nebula.*

1891·854	P = 317°·7	D = 132″·8
·893	318·1	131·7
1891·87	317·9	132·2

Applying these measures to the place of the star as given in the *Albany Catalogue*, we have for the nebula (1860):

R.A. $5^h\ 14^m\ 40^s$
Decl. + 3° 10′·4

No. 1931.

R.A. $5^h\ 22^m\ 9^s$
Decl. + 34° 8′

This is one of the discoveries of Herschel I. It has been drawn by Herschel II. (*Phil. Trans.*, 1833) and by D'Arrest. Herschel, in his observations of nebulæ, describes it as "a nebula including a triple star forming an equilateral triangle; sides=4″; stars=11, 12, 14 *m*." The triple was entered as No. 367 of his *Second Catalogue of Double Stars* (*Memoirs R.A.S.*, III.) with the following note:—"One of the most curious objects in the heavens. It is a triple star forming an equilateral triangle, and placed exactly in the centre of a small circular nebula which extends a little beyond the stars." No measures were made, but the distance was estimated as 7″.

In 1876 I looked at this with the 6-inch and found the nebula faint with that aperture, but the three stars were easily seen. With the 18½-inch in 1878 I noted several other stars in the group, just outside of the nebula. The 36-inch telescope now shows that one of the stars of the triangle is double, having an exceedingly faint attendant at a distance of a little more than 2″. This is a difficult pair under ordinary conditions with this telescope, and probably could not be seen at all in any other telescope with which this object has been observed. In the following measures, A, B, and C are the stars which form Herschel's triangle:

A and B.

1891·753	234°·3	7″·88	9·5 . . .	10
·766	233·0	8·16	9·5 . . .	10
·785	234·1	7·97	9·5 . . .	9·7
1891·77	233·8	8·00	9·5	9·9

A and C.

1891·753	309°·9	10″·33	. . .	11·5
·766	311·4	10·62	. . .	10·5
·785	309·0	10·65	. . .	11·5
1891·77	310·1	10·53	. . .	11·2

B and D.

1891·766	327°·9	2″·40	. . .	15
·785	321·4	2·22	. . .	15·5
1891·77	324·6	2·31		15·2

There is a 14 *m* star about 6″·8 from A in the direction of 18°·7. Herschel estimated the angles of A B and A C as 220° and 280° respectively, and the distance of each 7″. The only other measures which I have found were made with the large reflectors at Parsonstown. Some of the distant stars were observed, but the close star was not seen. The measures of the stars in the triangle are:

1873·775	239°·2	7′·1	A B.
1873·775	310·5	9·7	A C.

No. 1988.

R.A. 5ʰ 29ᵐ 4ˢ
Decl. + 21° 7′·7

This is Chacornac's so-called variable nebula near ζ *Tauri*. Dreyer states that Tempel pointed out many years ago that the supposed nebula was only the false image of the star. With the 36-inch there is not the least trace of any nebulosity in this place, and there is no doubt of the correctness of Tempel's explanation. Too much time has been wasted in looking for this object, and particularly since there was no reason whatever for believing in its existence after Chacornac himself failed to see it in 1862. Possibly some of the nebulæ may change, but the evidence of the actual disappearance of any object of this kind is very unsatisfactory, to say the least.

No. 2182.

R.A. 6ʰ 2ᵐ 42ˢ
Decl. − 6° 19′·0

This is a large nebula surrounding a wide double star. The nebula is IV. 38 (= *h* 381). The double star is H 2298. It is much too wide to be of any interest as a double star. The description in *h* 381 is, "The large star of a double star has a

very strong nebulous burr." The double was estimated (Fifth Catalogue) 90° : 35″ : 8–9 . . 10.

The large telescope shows that the principal star is centrally placed in a faint nebula which is considerably extended in all directions. It is very much like the planetary nebulæ so far as the central star is concerned, but lacks the definite boundary which characterises all nebulæ of that class. The large telescope also shows, what is of more interest than anything heretofore seen in connection with this object, that this central star is a very close pair. It is much too difficult to have been discovered with the large reflectors with which the nebula has been observed. I have not looked at it with the 12-inch here; but under favourable conditions the elongation would probably be detected, but it could not be properly measured with such an aperture. My measures are as follows:—

A and B.

	°	″		
1891·854	122·5	0·52	8·7 . . .	9·0
·859	126·2	0·48	8·5 . . .	8·7
·903	124·7	0·45	8·5 . . .	8·6
1891·87	124·5	0·48	8·6	8·8

AB and C (= H 2298).

	°	″	
1891·854	92·6	43·87	. . . 10·5
·859	92·8	44·00	. . . 11
·903	93·4	43·74	. . . 10·5
1891·87	92·9	43·87	10·7

There are no other measures of C. The principal star (AB.) is S.D. (6°) 1431 (= Schj. 2066), and its position for 1860 is:

$$\left.\begin{array}{l}\text{R.A. } 6^h\ 3^m\ 41^s{\cdot}6 \\ \text{Decl.} -6^\circ\ 18'{\cdot}3\end{array}\right\}$$

This is the place of the nebula, and therefore there is an error of about 1^m in the catalogue R.A. given above. This star is 9·0 *m* in the S.D., and 9·3 in Schjellerup.

There are a number of other nebulæ in this vicinity which were also examined. No. 2167 is described as "a star 7 *m*, with a pretty strong nebulous atmosphere." I could not see any difference between this and other stars of similar magnitude in the neighbourhood. I have sometimes thought that all of the stars in this region of the heavens had a glow about them not

generally found elsewhere, but this may be only optical or imaginary.

No. 2170 is described as "a star 9 *m*, in a very faint, pretty large nebula, extended in 170°." The nebulous light around the small star S.D. (6°) 1414 is very marked, and must be at least 2′ or 3′ in diameter. It is extended nearly north and south, as described in the Catalogue.

No. 2183, discovered by D'Arrest, is very small, and has a minute but relatively bright central condensation, which may be a faint star.

No. 2185 closely follows the last, but is too large to be seen to any advantage with the lowest micrometer eye-piece, and its extent could not be properly estimated. The brightest part of it seems to be about a star 10–11 *m*.

No. 7114.

R.A. $21^h\ 36^m\ 13^s$
Decl. $+42°\ 12'\cdot3$

This is the well-known "Nova Cygni." In looking up this star I have relied entirely upon the admirable catalogue and accompanying map of the surrounding stars by Copeland and Lohse (*Copernicus, II.*, 101). The arrangement of the Catalogue is perfect in every respect, and the chart showing the relative positions of the stars could not be improved. Both should serve as models for all work of this kind. I may say, in addition, that it is remarkably complete in reference to faint stars. The large telescope shows very little more.

I estimated this star (1891·731) as about 13·5 *m*. The nearest star to the "Nova" given by Copeland, 314°·2 : 19″·1, is a little fainter, or about 14 *m*. The 36-inch shows nothing closer. At times the new star did not seem to have a perfectly stellar appearance under moderately high powers, but rather to resemble an exceedingly minute nebula. This appearance, however, may not be real. The star is too faint to allow one to decide a question of this kind with any certainty. I did not make any measures from surrounding stars, as that has been very thoroughly done by the authors of the paper referred to. They have the following notes concerning some of the faint stars:—

No. 20 (14·5 *m*) "Perhaps double."
No. 40 (14·5 *m*) "This star is probably double or multiple."
No. 82 (13·9) "Double?"
No. 88 (13·8) "Double?"

I have examined these stars with the following results:—

No. 20. While this is not double, strictly speaking, there is another star of nearly the same magnitude at a distance of 15″ or 20″, and that is probably what is referred to.

No. 40. There are two faint stars about 8″ or 10″ apart.

No. 82. I could not see any other star near this.

No. 88. This is a very faint pair of stars, with a distance of perhaps 2″ or 3″.

No. 7173.

R.A. $21^h\ 53^m\ 53^s$ }
Decl. $-32°\ 38'\cdot1$ }

There are other nebulæ in this group (Nos. 7172, 7174, and 7176). They were accidentally picked up with the 12-inch, and, in consequence of a blunder in referring to Dreyer, they were supposed to be new, and therefore observed as given below. The comparison star is from the *Cordoba Catalogue.*

Gould 30117 *and No.* 7173.

1891·758	P = 30°·1	D = 361″·8

Gould 30117 *and No.* 7176.

1891·758	P = 44°·9	D = 350″·1

These measures give for the nebulæ (1860):

No. 7173	R.A. $21^h\ 53^m\ 53^s$ Decl. $-32°\ 38'\cdot7$
No. 7176	R.A. $21^h\ 53^m\ 58^s$ Decl. $-32°\ 39'\cdot8$

The last-named, No. 7176, is double in Herschel, the companion being No. 7174. With the 36-inch, with which it was subsequently examined, it appears to be one nebula, with a second very faint nucleus or condensation. I made the following measures with the large telescope (1891·766):—

No. 7173 and No. 7176	P = 130°·1	D = 89″·44
No. 7176 and No. 7174	238·2	25·62

No. 7172, which is about 5½′ north of No. 7173, was not measured.

No. 7287.

R.A. $22^h\ 50^m\ 54^s$ }
Decl. $-22°\ 51'\cdot1$ }

Discovered by Müller at the McCormick Observatory. It is described, "Excessively faint, slightly nebulous double star." I found two very faint objects about 20″ apart. It may possibly be a double nebula, but the following component seems to be a faint star only. The preceding one is undoubtedly a faint nebula. It is a little brighter in the middle, giving it a stellar appearance. Rough measures of the two give P=60°·5; D=20″·7.

No. 7403.

R.A. $22^h\ 45^m\ 57^s$
Decl. $+0^\circ\ 44'\cdot3$

This was discovered by Coolidge at the Harvard Observatory. The description is, "Star slightly nebulous." A careful examination (1891·728) shows that there is certainly nothing of the kind in the assigned place. It should be about 7′ north of a 9 *m* star, D.M. (0°) 4935. In sweeping over this region I found a moderately bright nebula, which is probably the object in question. It is 38^s following, and 39″·5 north of the D.M. star mentioned above. This gives as the place of the nebula (1860):

R.A. $22^h\ 46^m\ 37.$
Decl. $+0^\circ\ 38'\cdot2$

The nebula has a 10 *m* star 113″·0 distant in the direction of 230°·4.

About 15′ north of this, and a little preceding, there is a cluster of five faint nebulæ (Nos. 7396, 7397, 7398, 7401, and 7402), all but the first discovered with the Rosse reflector. These were readily found, and appeared to be in the catalogue places.

No. 7447.

R.A. $22^h\ 53^m\ 6^s$
Decl. $-11^\circ\ 16'\cdot7$

Described in the Catalogue, "Star 11–12 *m* in neb." In the final notes it is stated that this was not found by Tempel on several occasions (*Ast. Nach.* 2284). I examined this region very thoroughly on October 29 without finding anything in the least suggestive of a nebula of any kind. In or very near the catalogue place there is a 11–12 *m* star, but there is nothing nebulous about it. A little *np* the place there is a faint triple star, A.B. 200° : 2″; A.C. 270° : 10″, and perhaps with a small aperture this group might be mistaken for a nebula. The place was carefully examined again on a subsequent night with similar results. This object certainly does not exist.

Nos. 7472, 7477, and 7482.

These three nebulæ are given in the General Catalogue as follows:—

	h m s	° ′	
No. 7472	22 56 34	+2 18	O. Struve
No. 7477	22 57 34	+2 21·9	D'Arrest
No. 7482	22 58 33	+2 19	Marth

It seemed a little strange that three separate objects should be distributed in this way, and a careful examination showed that all the observations related to one object. I went over the

whole vicinity on two nights, and I am certain that there is only one nebula here. That is $1^m\ 23^s$ preceding, and $30''\cdot4$ south of the 8·2 *m* star, D.M. (2°) 4609 (=Lalande 45206). Applying these differences to the place of the star from Schjellerup, we have for the nebula (1860):

$$\left.\begin{array}{l}\text{R.A. } 23^h\ 58^m\ 31^s \\ \text{Decl.} +2^\circ\ 17'\cdot2\end{array}\right\}$$

This agrees substantially with Marth's position, and his description is also correct.

No. 7693.

$$\left.\begin{array}{l}\text{R.A. } 23^h\ 25^m\ 59^s \\ \text{Decl.} -2^\circ\ 3'\cdot9\end{array}\right\}$$

This was discovered by Hall in 1881, while observing Faye's Comet (*Ast. Nach.* 2394). It is described as a "Small nebula, or nebulous star." This was examined on two nights with the large telescope. It is a small faint nebula, a little brighter in the middle, but there is nothing stellar in its appearance. There is a small star near it with which it was compared:—

Neb. and 13m Star.

1891·675 $P = 111^\circ\cdot2$ $D = 83''\cdot72$

For place it was compared with the nearest catalogue star, S.D. (2°) 5982:—

Star and Neb.

1891·675 $P = 112^\circ\cdot4$ $D = 277''\cdot4$

Applying these differences to Lamont's place of the S.D. star, gives for the nebula (1860):—

$$\left.\begin{array}{l}\text{R.A. } 23^h\ 25^m\ 59^s \\ \text{Decl.} -2^\circ\ 3'\cdot7\end{array}\right\}$$

No. 7804.

$$\left.\begin{array}{l}\text{R.A. } 23^h\ 54^m\ 9^s \\ \text{Decl.} +6^\circ\ 58'\cdot1\end{array}\right\}$$

The description is, "Very faint double star, nebulous?"; and in the final notes Dreyer says: "Found by Schweizer (*Observations de Moscou, II.*, 115), and observed by Bredechin in 1875. Described as F, E, a little brighter *sp*. Engelhardt in four observations could only see a double star without nebulosity."

I examined this region very carefully on two nights. The faint pair mentioned was found; but there was no trace of nebulosity about it, or anywhere in the vicinity. I measured the double star as follows:—

1891·675 $55^\circ\cdot6$ $9''\cdot79$ 12·5 . . . 13

To find out whether this is in the place assigned to the supposed nebula, I measured it directly from the nearest catalogue star, D.M. (6°) 5233. This is a small star, 8·7 *m*. The prin-

cipal star of the faint pair is 160″·4 distant in the direction of 350°·0, giving for the place of the nebula (1860):—

$$\left.\begin{array}{l}\text{R.A. } 23^h\ 54^m\ 7^s \\ \text{Decl.} +6°\ 58'{\cdot}2\end{array}\right\}$$

This shows that it was certainly the object taken for a nebula by Schweizer, and observed by Bredechin. The comparison star used above is a wide double. A single setting of the wires gave 266°·1 : 15″·2. I ascertained later that it had been measured by Dunér in 1869. He found 265°·3 : 15″·26.

New Nebulæ.

In addition to the new nebulæ incidentally noted in the foregoing observations, I found the two given below. They are both in the field with a 9·5 *m* star, D.M. (40°) 608, and I have measured them directly from this star. The following nebula of the two is double. The nuclei are small, and fairly well defined. The other is only a little brighter in the centre, and considerably diffused. I have called the magnitudes of the nuclei of the double nebula each 14.

D.M. Star and Neb. I.

1891·673	P = 288°·8	D = 109″·72
·689	288·8	110·83
1891·68	288·8	110·27

D.M. Star and Neb. II.

1891·673	285°·5	169″·19
·689	285·6	169·34
1891·68	285·5	169·26

Neb II. (Nuclei).

1891·673	323°·1	17″·02
·689	321·7	18·06
1891·68	322·4	17·54

Applying these measures to the D.M. place of the star, we have for the nebulæ (1860):—

	h m s	° ′
Neb. I.	2 40 49	+40 28·5
Neb. II.	2 41 12	+40 28·6

The only catalogue nebula in the immediate vicinity is one discovered by Swift (No. 1086). This is larger than I., and brighter than either.

Mount Hamilton:
1892 *January* 30.

Ephemeris for Physical Observations

Greenwich Noon.	Angle of Position of ♃'s Axis. P	L−O.	Diff.	B	Annual Parallax. A−L.	Apparent Diameter. Equat.	Phase.	Polar.
1892.	°	°		°	°	″	″	″
May 21	335·634	239·669	403	+2·503	− 8·438	34·76	0·19	32·53
23	335·684	240·072	398	2·520	8·658	34·90	·20	32·66
25	335·734	240·470	393	2·536	8·872	35·04	·21	32·79
27	335·785	240·863	386	2·553	9·081	35·19	·22	32·93
29	335·836	241·249	380	2·569	9·283	35·34	·23	33·07
31	335·887	241·629	374	+2·585	− 9·480	35·49	0·24	33·22
June 2	335·939	242·003	367	2·601	9·670	35·65	·25	33·37
4	335·991	242·370	361	2·617	9·854	35·82	·26	33·52
6	336·042	242·731	354	2·633	10·032	35·99	·28	33·68
8	·093	243·085	347	2·648	10·202	36·16	·29	33·84
10	·144	243·432	340	+2·664	−10·366	36·34	0·30	34·01
12	·195	243·772	333	2·680	10·522	36·53	·31	34·18
14	·246	244·105	325	2·695	10·671	36·72	·32	34·36
16	·296	244·430	317	2·710	10·812	36·91	·33	34·54
18	·346	244·747	309	2·725	10·946	37·11	·34	34·72
20	·395	245·056	301	+2·740	−11·072	37·31	0·35	34·91
22	·444	245·357	292	2·755	11·189	37·51	·36	35·11
24	·492	245·649	283	2·770	11·297	37·73	·37	35·31
26	·538	245·932	274	2·785	11·397	37·94	·37	35·51
28	·584	246·206	265	2·800	11·488	38·16	·38	35·71
30	·629	246·471	255	+2·814	−11·569	38·38	0·39	35·92
July 2	·673	246·726	246	2·828	11·641	38·61	·40	36·13
4	·715	246·972	236	2·842	11·703	38·84	·40	36·35
6	·756	247·208	226	2·856	11·756	39·08	·41	36·57
8	·796	247·434	216	2·870	11·798	39·32	·42	36·80
10	·834	247·650	205	+2·883	−11·830	39·56	0·42	37·02
12	·871	247·855	195	2·896	11·851	39·81	·42	37·25
14	·906	248·050	183	2·909	11·862	40·06	·43	37·49
16	·940	248·233	172	2·922	11·862	40·31	·43	37·73
18	336·972	248·405	160	2·935	11·850	40·57	·43	37·97
20	337·001	248·565	149	+2·948	−11·827	40·83	0·43	38·21
22	·029	248·714	137	2·960	11·792	41·09	·43	38·45
24	·055	248·851	125	2·972	11·746	41·36	·43	38·70
26	·079	248·976	113	2·984	11·687	41·62	·43	38·95
28	·100	249·089	100	2·995	11·616	41·89	·43	39·21
30	337·119	249·189		+3·006	−11·533	42·07	0·43	39·46

of Jupiter, 1892. By. A. Marth.

Greenwich Noon.	Longitude of ♃'s Central Meridian (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A−O.	B
1892.	°	°	°	m	°	°
May 21	340·93	334·58	+0·31	46·586	231·2345	+2·3953
23	296·44	274·82	·33	46·402	231·4180	2·4015
25	251·96	215·08	·34	46·213	231·6014	2·4076
27	207·48	155·35	·36	46·020	231·7849	2·4137
29	163·02	95·62	·38	45·823	231·9684	2·4197
31	118·56	35·90	+0·39	45·621	232·1519	+2·4257
June 2	74·11	336·19	·41	45·415	232·3354	2·4317
4	29·67	276·49	·42	45·205	232·5189	2·4377
6	345·24	216·80	·44	44·991	232·7024	2·4436
8	300·82	157·12	·45	44·774	232·8859	2·4496
10	256·41	97·44	+0·47	44·553	233·0694	+2·4555
12	212·00	37·78	·48	44·329	233·2529	2·4614
14	167·61	338·12	·50	44·102	233·4364	2·4673
16	123·23	278·48	·51	43·871	233·6199	2·4731
18	78·85	218·84	·52	43·638	233·8035	2·4789
20	34·49	159·21	+0·53	43·402	233·9870	+2·4846
22	350·13	99·60	·54	43·163	234·1705	2·4904
24	305·79	39·99	·55	42·922	234·3541	2·4961
26	261·45	340·39	·56	42·678	234·5377	2·5018
28	217·13	280·81	·57	42·433	234·7212	2·5075
30	172·81	221·23	+0·58	42·185	234·9048	+2·5132
July 2	128·51	161·67	·59	41·936	235·0884	2·5188
4	84·21	102·11	·60	41·686	235·2719	2·5244
6	39·93	42·57	·60	41·435	235·4555	2·5300
8	355·66	343·04	·61	41·182	235·6391	2·5355
10	311·40	283·51	+0·61	40·929	235·8227	+2·5410
12	267·15	224·00	·61	40·675	236·0063	2·5465
14	222·91	164·50	·61	40·421	236·1899	2·5520
16	178·68	105·01	·61	40·167	236·3735	2·5574
18	134·46	45·53	·61	39·913	236·5571	2·5628
20	90·26	346·07	+0·61	39·659	236·7407	+2·5682
22	46·06	286·61	·60	39·405	236·9243	2·5736
24	1·88	227·17	·60	39·153	237·1079	2·5790
26	317·71	167·73	·59	38·901	237·2915	2·5843
28	273·55	108·31	·59	38·651	237·4751	2·5896
30	229·40	48·90	+0·58	38·403	237·6587	+2·5948

The angle L − O + 180° is the jovicentric longitude of the Earth, reckoned in the assumed plane of *Jupiter's* equator from O, the point of the vernal equinox of *Jupiter's* northern hemisphere or the point of the descending node of the planet's equator on its orbit. B denotes the jovicentric latitude of the latitude of the Earth above *Jupiter's* equator. The annual parallax A—L is the difference between the jovicentric longitudes of the Sun and Earth. For the computation of the apparent diameters I have adopted the values deduced by Schur (*Astr. Nachr.*, vol. 129, p. 14) from his measurements made with the new Göttingen heliometer about the time of the last opposition. It were much to be desired that the several powerful heliometers now available should be employed about the time of the next opposition, while the phase is practically insensible, for measuring the equatorial and polar diameter of the planet, so that their united testimony might indicate the values, which are likely to come nearest to the true ones.

The two values of the "Longitude of ♃'s Central Meridian" given for each date are computed with the same rates of rotation as in the ephemerides for some preceding years; but as the motion of the great spot has again been slackening during the last season, I have restored in "System II." the zero-meridian to the place adopted in the Ephemeris for 1890, from which it was put back 10° in the Ephemeris for 1891, so that the longitudes of the spot computed from the data for the last apparition must be diminished 10°, in order to conform with the computed longitudes of 1890 and with those of the present Ephemeris. The "System I." of longitudes has been continued unaltered, as Mr. A. Stanley Williams' observations of a number of equatorial spots, which he has kindly communicated, render any alteration for the present undesirable.

The addition of the "correction for phase" to the longitudes of the central meridian gives the longitudes of the meridian which bisects the illuminated disc. The following is a list of Greenwich mean times, when the zero-meridian in the assumed two systems of longitudes will pass the middle of the illuminated disc:—

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
1892.	h m	h m	1892.	h m	h m
May 21	10 21·4	10 37·3	24	7 15·5	8 7·7
	20 12·0	20 33·1		17 6·1	18 3·5
22	15 53·1	16 24·6	25	12 47·3	13 55·0
23	11 34·3	12 16·2		22 37·9	23 50·8
	15 36·0 ∓ occultation of ✱ 73 Piscium. *V.* note at end of list.		26	8 28·4	9 46·6
				18 19·0	19 42·3
			27	14 0·2	15 33·8
	21 24·9	22 12·0	28	9 41·4	11 25·4

	I. (877°90)		II. (870°27)			I. (877°90)		II. (870°28)	
1892.	h	m	h	m	1892.	h	m	h	m
	19	31·9	21	21·1		21	49·8	17	57·0
29	5	22·5	7	16·9	18	7	39·3	13	48·5
	15	33·1	17	12·6		17	30·9	23	44·2
30	10	54·3	13	4·2	19	13	12·0	9	39·9
	20	44·9	22	59·9		23	2·6	19	35·7
31	6	35·4	8	55·7	20	8	53·1	5	31·4
	16	26·0	18	51·4		18	43·7	15	27·1
June 1	12	7·2	14	43·0	21	14	24·8	11	18·6
2	7	48·3	10	34·5		24	15·3	21	14·3
	17	38·9	20	30·2	22	10	5·9	7	10·0
3	13	20·1	6	26·0		19	56·4	17	5·8
	23	10·6	16	21·7	23	5	46·9	12	57·2
4	9	1·2	12	13·2		15	37·5	22	52·9
	18	51·8	22	9·0	24	11	18·6	8	48·6
5	14	32·9	18	0·5		21	9·1	18	44·4
6	10	14·1	13	52·0	25	6	59·7	14	35·8
	20	4·6	23	47·7		16	50·2	24	31·5
7	5	55·2	9	43·5	26	12	31·3	10	27·2
	15	45·8	19	39·2		22	21·8	20	23·0
8	11	26·9	5	35·0	June 27	8	12·4	6	18·7
	21	17·5	15	30·7		18	2·9	16	14·4
9	7	8·0	11	22·2	28	13	44·0	12	5·8
	16	58·6	21	18·0		23	34·5	22	1·5
10	12	39·7	7	13·7	29	9	25·0	7	57·2
	22	30·3	17	9·5		19	15·6	17	52·9
11	8	20·9	13	0·9	30	14	56·6	13	44·4
	18	11·4	22	56·7		24	47·2	23	40·1
12	13	52·5	8	52·4	July 1	10	37·7	9	35·8
	23	43·1	18	48·2		20	28·2	19	31·5
13	9	33·7	14	39·6	2	6	18·8	5	27·2
	19	24·2	24	35·4		16	9·3	15	22·9
14	15	5·3	10	31·1	3	11	50·4	11	14·3
	24	55·9	20	26·9		21	40·9	21	10·0
15	10	46·5	6	22·6	4	7	31·4	7	5·8
	20	37·0	16	18·3		17	21·9	17	1·5
16	6	27·6	12	9·8	5	13	3·0	12	52·9
	16	18·1	22	5·5		22	53·5	22	48·6
17	11	59·2	8	1·3	6	8	44·0	8	44·3

	I.	II.		I.	II.
	(877°90)	(870°27)		(877°90)	(870°28)
1892.	h m	h m	1892	h m	h m
	18 34·6	18 40·0	19	11 40·4	4 30·7
7	14 15·6	14 31·4		21 30·9	14 26·4
8	0 6·1	0 27·1	20	7 21·4	10 17·7
	9 56·6	10 22·8		17 11·9	20 13·4
	19 47·2	20 18·5	21	12 52·9	6 9·1
9	5 37·7	6 14·2		22 43·4	16 4·8
	15 28·2	16 9·9	22	8 33·9	11 56·1
10	11 9·2	12 1·3		18 24·4	21 51·8
	20 59·8	11 56·9	23	4 14·9	7 47·5
11	6 50·3	7 52·6		14 5·4	17 43·1
	16 40·8	17 48·3	24	9 46·4	13 34·5
12	12 21·8	13 39·7		19 36·9	23 30·1
	22 12·3	23 35·4	25	5 27·4	9 25·8
13	8 2·8	9 31·1		15 17·9	19 21·5
	17 53·4	19 26·8	26	10 58·9	5 17·2
14	13 34·4	5 22·5		20 49·4	15 12·8
	23 24·9	15 18·2	27	6 39·9	11 4·2
15	9 15·4	11 9·5		16 30·3	20 59·8
	19 5·9	21 5·2	28	12 11·3	6 55·5
16	4 56·4	7 0·9		22 1·8	16 51·1
	14 46·9	16 56·6	29	7 52·3	12 42·5
17	10 27·9	12 48·0		17 42·8	22 38·1
	20 18·4	22 43·6	30	3 33·3	8 33·8
18	6 8·9	8 39·3		13 23·7	18 29·4
	15 59·4	18 35·0	31	9 4·7	4 25·1

(*To be continued.*)

Note on the Occultation of the Star 73 Piscium $6^{m}\cdot4$ *by Jupiter on* 1892 *May* 23. By A. Marth.

Assuming the apparent place of the star, as derived from the Greenwich Ten-Year Catalogue for 1880, to be α 0^{h} 59^{m} $16^{s}\cdot29$ $\delta+5^{\circ}$ $4'$ $36''\cdot8$, and referring it to the *Nautical Almanac* places of *Jupiter*, the rectangular co-ordinates of the star $x=s\sin(p-P)$ and $y=s\cos(p-P)$ referred to the axes of the disc of *Jupiter* and corrected for parallax will be

May 23. G.M.T.		$x=+0''\cdot651\,\rho_{,}+$		$y=+1''\cdot442\,\rho_{,}+$	
h	m	$''$		$''$	
14	0	$+49''\cdot23-1''\cdot448\,\rho'\cos(\lambda-$	$14^{\circ}\cdot96)$	$+12''\cdot33$	$+0''\cdot666\,\rho'\cos(\lambda-\;1^{\circ}\cdot60)$
	20	39·26	$-\;9\cdot95$	12·75	$+\;3\cdot41$
	40	29·29	$-\;4\cdot93$	13·16	8·42
15	0	19·33	$+\;0\cdot08$	13·57	13·44
	20	$+\;9\cdot36$	5·09	13·98	18·45
	40	$-\;0\cdot60-1\cdot448\,\rho'\cos(\lambda+$	$10\cdot10)$	$+14\cdot40$	$+0\cdot666\,\rho'\cos(\lambda+23\cdot46)$
16	0	10·56	15·11	14·81	28·48
	20	20·52	20·12	15·22	33·49
	40	30·48	25·13	15·63	38·50
17	0	$-40\cdot44$	30·14	16·04	43·52
	20	$-50\cdot39-1\cdot448\,\rho'\cos(\lambda+$	$35\cdot15)$	$+16\cdot45$	$+0\cdot666\,\rho'\cos(\lambda+48\cdot53)$

where λ denotes the longitude, east of Greenwich, of the place of observing, and $\rho_{,}$ and ρ' its distances from the plane of the equator and from the axis of the Earth.

The occultation of the star takes place so near the northern limb that any small error of the differences of declination will alter the times of the star's disappearance, and affects reappearance to such a degree as to render any prediction untrustworthy. Nevertheless, the knowledge of the times of the middle of the occultation and of its semiduration, though computed on the assumption of the correctness of the tabular values, may be of service, and these times are therefore given for a few observatories.

	Middle of Occultation. G.M.T.	Local M.T.	Semi-duration.
	h m	h m	m
Cape	15 34·7	16 42·6	∓ 18·5
Algiers	35·9	15 48·1	10·0
Madrid	36·0	15 21·1	9·5
Nice	36·3	16 5·5	9·4
Paris	36·5	15 45·8	8·8
Greenwich ...	36·6	15 36·6	8·6
Dublin	15 36·7	15 11·3	8·4

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LII. MAY 13, 1892. No. 7

E. B. KNOBEL, Esq., President, in the Chair.

The Rev. W. H. Addison, 8 West Chapel Street, Mayfair, W.;
Henry Baynham, Lieutenant R.N.R., Captain of H.M.S. "Wellesley," Training Ship, North Shields;
Humphrey Barker Chamberlin, 1033 Sixteenth Street, Denver, Colorado, U.S.A.;
Otto Jaffe, Kin Edar, Strandtown, Belfast, Ireland;
Charles Henry Johns, M.A., Althorpe House, Waverley Grove, Hendon, N.W.;
William Grant MacGregor, F.R.G.S., 18 Coleman Street, E.C.;
Captain R. Reynolds, Lieutenant R.N.R., Union Steamship "Pretoria," Southampton;
Albert Edward Watson, B.A., F.R.Met.Soc., Whitgift Grammar School, and 8 St. John's Grove, Croydon,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

The Rev. James Barnes Brearley, M.A., F.R.G.S., St. James's Church, Oldham, Lancashire (proposed by A. de Boë);
Herbert Hancock, M.A., F.R.Met.Soc., Lecturer on Geometry to the Architectural Association, and Mathematical Master in Bancroft's School, Woodford, Essex (proposed by W. H. Besant);
Thomas Torrens Knowles, M.A., Cambridge Extension Lecturer in Chemistry, Lancashire County Council Lecturer in Physics, Mathematical and Science Master,

Royal Grammar School, Lancaster (proposed by John Bone);

Alfred Thomas Odell-Lorrell, Science Lecturer and Examiner, 1 St. Mary's Grove, Chiswick, W. (proposed by D. Milligan);

Edward Stroud, Prisca Coborn Foundation School, Tredegar Square, E. (proposed by J. McCarthy);

John Tatlock, Jun., M.A., New York City, U.S.A. (proposed by S. W. Burnham).

The following were proposed by the Council as Associates of the Society:—

W. L. Elkin, Yale College Observatory, New Haven, Connecticut, U.S.A.;

J. C. Kapteyn, Observatory, Gröningen, Holland;

Hugo Seeliger, Royal Observatory, Munich, Bavaria;

Hermann Struve, Observatory, Pulkowa, Russia.

Seventy-seven presents were announced as having been received since the last meeting, including, amongst others:—

Original negatives of *Jupiter* (12 plates), taken with the great telescope of the Lick Observatory, presented by the Observatory; Original negative of Swift's Comet, taken at the Sydney Observatory, presented by H. C. Russell; Photograph of the region surrounding η *Argûs*, enlargement from a negative taken by Dr. Gill at the Royal Observatory, Cape of Good Hope, presented by the President; Photographs of the "Crab" Nebula (1 M *Tauri*), presented by Isaac Roberts; R. Wolf, *Geschichte der Astronomie*, third half-volume, presented by the author; Photograph of the Total Solar Eclipse of 1871 (positive copy on glass), taken in Java, presented by Professor Oudemans; Oxygen bottle for use with the lantern at evening meetings, presented by E. Ristori.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1891; *and a Comparison of the Results with the Tabular Places from Hansen's Lunar Tables.* By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The present paper contains the observations of the Right Ascensions and North Polar Distances of the Moon, made at the Radcliffe Observatory during the year 1891. These results are here compared with those deduced from Hansen's Lunar Tables on two suppositions:—

(1) That the mean times found in the usual way, from the sidereal times at mean noon given in the *Nautical Almanac*, were not altered in scale, or affected with any different systematic errors of determination, by

the adoption in 1864 of a different ratio of the Julian year of $365\frac{1}{4}$ "mean solar days" to the mean tropical year.

(2) That the "mean times," which accurately correspond to a given "sidereal time of a meridian," were necessarily changed in 1864 by the use of a different ratio of the "Julian year" and therefore of the "mean solar day," to the mean tropical year, to fix the tabular Right Ascensions of the clock stars at the meridian transits. It is from these tabular Right Ascensions of the clock stars that the observed Right Ascensions are deduced by the aid of clocks; and the Right Ascensions thus found are finally rendered definite by a direct reference to the positions of the Sun deduced from the North Polar Distances and Obliquities of the Ecliptic.

In the Appendix to the *Monthly Notices*, vol. l., will be found the results of a comparison between the Greenwich Lunar Observations, 1847–1861, and Hansen's Tables, of greater accuracy than had before been available for use; and these results have been utilised to form the mean results given in Table III.

An examination of the residual errors shows that the motion of the Moon was closely represented by Hansen's Tables during the period 1847–1863, although periodical errors of no inconsiderable amount, due either to defects of theory or to imperfections in the practical methods of comparing the theoretical and observational results, are shown to exist.

The mean annual error in longitude of Hansen's Tables from 1847 to 1863 is, however, only $-1''\cdot85$, and no law of regular increase is apparent; but Table III. shows that when the time, *t*, is found as at present, the mean annual error has increased since 1863 at an average rate of $0''\cdot75$ per annum, and that the error now amounts to $+19''$. The mean annual error of Hansen's Tables from 1864 to 1891 taken out with the *corrected* argument is $-1''\cdot49$, which differs but very slightly from the mean error between 1847 and 1863.

For facilities for an accurate comparison between Hansen's Lunar Tables and Observations I am again indebted to the places published in the *Connaissance des Temps*.

TABLE I.

Radcliffe Observations of the Moon, 1891.

R.A.'s and N.P.D.'s of the Centre of the Moon, 1891; *compared with Hansen's Tabular Places*, **Uncorrected** *and* **Corrected** *for the change in the Unit of Mean Time introduced in the year* 1864.

Day, 1891.		Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
		s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Jan.	4	40·04	R.	II.	14 20 3·13	4·12	+0·99	−1·33	−0·34	S.	100 33 55·53	63·31	+ 7·78	− 8·37	−0·59
	5	40·05	R.	II.	15 11 8·18	9·27	+1·09	−1·43	−0·34	S.	105 32 30·41	37·73	+ 7·32	− 7·62	−0·30
	16	40·09	R.	I.	1 19 1·12	2·19	+1·07	−1·40	−0·33	S.	86 10 50·53	42·12	− 8·41	+ 9·79	+1·38
	17	40·09	R.	I.	2 10 42·46	43·65	+1·19	−1·39	−0·20	S.	80 21 10·66	2·68	− 7·98	+ 8·98	+1·00
	21	40·11	R.	I.	5 46 33·76	35·14	+1·38	−1·51	−0·13	N. & S.	65 25 6·06	3·46	− 2·60	+ 2·29	−0·31
	22	40·11	W.	I.	6 42 53·89	55·26	+1·37	−1·51	−0·14	N.	64 40 1·95	2·50	+ 0·55	+ 0·13	+0·68
	24	40·12	R.	I. & II.	8 32 33·85	35·06	+1·21	−1·43	−0·22	N.	67 3 34·65	38·20	+ 3·55	− 3·85	−0·30
	29	40·14	F. B.	II.	12 29 40·60	41·82	+1·22	−1·20	+0·02	S.	88 7 33·44	39·11	+ 5·67	− 8·54	−2·87
Feb.	1	40·15	R.	II.	14 48 27·24	28·24	+1·00	−1·35	−0·35	S.	103 39 8·07	16·07	+ 8·00	− 7·80	+0·20
	16	40·21	F. B.	I.	4 33 18·45	19·71	+1·26	−1·50	−0·24	S.	68 10 47·93	44·30	− 3·63	+ 5·00	+1·37
	17	40·22	R.	I.	5 29 9·92	11·03	+1·11	−1·51	−0·40	S.	65 43 39·01	37·41	− 1·60	+ 2·91	+1·31
	23	40·24	F. B.	II.	10 44 31·97	33·18	+1·21	−1·26	−0·05	N.	76 38 20·36	27·75	+ 7·39	− 7·42	−0·03
	25	40·25	R.	II.	12 14 49·18	50·13	+0·95	−1·21	−0·26	S.	86 33 31·22	38·62	+ 7·40	− 8·56	−1·16
	26	40·25	F. B.	II.	12 59 12·62	13·73	+1·11	−1·21	−0·10	S.	91 51 16·31	25·12	+ 8·81	− 8·68	+0·13

Day, 1891.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. Uncorrected.	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. Corrected.	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. Uncorrected.	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. Corrected.
	s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Feb. 27	40·26	W.	II.	13 44 19·54	20·76	+1·22	−1·24	−0·02	S.	97 8 12·04	23·81	+11·77	−8·50	+3·27
Mar. 20	40·34	R.	I.	8 50 47·95	49·06	+1·11	−1·40	−0·29	N.	67 44 28·49	31·84	+3·35	−4·58	−1·23
21	40·35	F. B.	I.	9 41 8·21	9·32	+1·11	−1·33	−0·22	N.	71 1 3·60	7·45	+3·85	−6·04	−2·19
26	40·37	F. B.	II.	13 29 40·56	41·63	+1·07	−1·24	−0·17	S.	95 35 35·53	44·86	+9·33	−8·74	+0·59
30	40·38	F. B.	II.	16 52 23·07	24·40	+1·33	−1·56	−0·23	S.	113 13 49·45	56·63	+7·18	−4·44	+2·74
Apr. 17	40·45	R.	I.	9 23 36·90	37·86	+0·96	−1·37	−0·41	N.	69 33 51·90	55·98	+4·08	−5·63	−1·55
20	40·47	W.	I.	11 44 19·43	20·31	+0·88	−1·22	−0·34	N.	82 55 53·93	59·07	+5·14	−8·50	−3·36
22	40·47	R.	I.	13 13 46·35	47·20	+0·85	−1·24	−0·39	N.	93 41 56·94	64·64	+7·70	−8·95	−1·25
23	40·48	F. B.	I. & II.	13 59 55·42	56·54	+1·12	−1·29	−0·17	N. & S.	99 5 36·23	43·13	+6·90	−8·67	−1·77
25	40·49	R.	II.	15 39 43·47	44·56	+1·09	−1·45	−0·36	S.	108 45 32·61	37·83	+5·22	−6·82	−1·60
May 15	40·57	R.	I.	9 53 41·54	42·45	+0·91	−1·34	−0·43	N.	71 42 5·56	10·40	+4·84	−6·51	−1·67
16	40·57	F. B.	I.	10 41 19·62	20·70	+1·08	−1·27	−0·19	N.	76 0 25·63	30·46	+4·83	−7·57	−2·74
19	40·58	R.	I.	12 56 2·49	3·37	+0·88	−1·23	−0·35	N.	91 29 28·23	34·97	+6·74	−8·99	−2·25
31	40·63	R.	II.	0 10 39·28	40·63	+1·35	−1·45	−0·10	N.	94 2 37·28	26·16	−11·12	+10·46	−0·66
June 12	40·68	R.	I.	10 22 2·39	3·35	+0·96	−1·31	−0·35	N.	74 10 34·48	39·92	+5·44	−7·23	−1·79
16	40·69	R.	I.	13 22 4·81	5·61	+0·80	−1·24	−0·44	N.	94 40 8·05	15·73	+7·68	−8·93	−1·25
19	40·71	R.	I.	15 49 59·28	60·62	+1·34	−1·50	−0·16	N.	109 33 32·90	39·38	+6·48	−6·70	−0·22
20	40·71	F. B.	I.	16 47 8·19	9·76	+1·57	−1·62	−0·05	N. & S.	113 7 50·76	55·49	+4·73	−4·87	−0·14

Day, 1891.		Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
		s			h m s	s	s	s	s		° ′ ″	″	″	″	″
June	25	40·73	F. B.	II.	22 2 49·13	50·94	+1·81	−1·61	+0·20	N.	107 28 46·57	37·99	− 8·58	+ 8·21	−0·37
July	16	40·81	R.	I.	15 25 21·99	23·01	+1·02	−1·43	−0·41	N.	107 43 13·74	17·78	+ 4·04	− 7·22	−3·18
	17	40·82	F. B.	I.	16 19 49·15	50·53	+1·38	−1·55	−0·17	N.	111 41 25·32	30·96	+ 5·64	− 5·73	−0·09
	24	40·85	R.	II.	23 35 29·25	30·83	+1·58	−1·52	+0·06	N.	97 55 36·25	25·52	−10·73	+10·53	−0·20
	27	40·86	F. B.	II.	2 16 26·27	27·82	+1·55	−1·47	+0·08	N.	78 50 50·82	41·81	− 9·01	+ 9·51	+0·50
Aug.	13	40·93	W.	I.	15 55 10·52	11·79	+1·27	−1·47	−0·20	N.	110 16 23·34	27·21	+ 3·87	− 6·30	−2·43
	27	40·98	W.	II.	5 44 36·03	37·76	+1·73	−1·61	+0·12	N.	64 23 41·36	39·52	− 1·84	+ 2·32	+0·48
Sept.	10	41·04	W.	I.	16 28 23·14	24·42	+1·28	−1·51	−0·23	N.	112 40 46·60	49·83	+ 3·23	− 5·18	−1·95
	11	41·04	R.	I.	17 25 23·73	24·78	+1·05	−1·62	−0·57	N.	115 13 23·27	27·23	+ 3·96	− 3·12	+0·84
	12	41·05	F. B.	I.	18 26 10·94	12·38	+1·44	−1·71	−0·27	S.	116 22 19·82	17·49	− 2·33	− 0·57	−2·90
	14	41·05	W.	I.	20 33 46·97	48·47	+1·50	−1·75	−0·25	S.	113 32 28·82	25·04	− 3·78	+ 5·27	+1·49
	15	41·06	R.	I.	21 36 58·10	59·55	+1·45	−1·71	−0·26	S.	109 30 30·67	22·47	− 8·20	+ 7·92	−0·28
	16	41·06	F. B.	I.	22 38 2·82	4·40	+1·58	−1·64	−0·06	S.	104 2 12·08	1·85	−10·23	+ 9·97	−0·26
	23	41·09	R.	II.	5 24 9·20	10·86	+1·66	−1·65	+0·01	N.	64 43 19·68	16·35	− 3·33	+ 3·23	−0·10
Oct.	12	41·17	F. B.	I.	21 8 33·90	35·35	+1·45	−1·67	−0·22	S.	111 42 38·62	34·72	− 3·90	+ 6·61	+2·71
	14	41·17	R.	I.	23 6 50·07	51·29	+1·22	−1·58	−0·36	S.	101 5 10·14	0·49	− 9·65	+10·56	+0·91
	15	41·18	W.	I.	0 3 40·45	41·85	+1·40	−1·56	−0·16	S.	94 28 43·26	33·60	− 9·66	+11·50	+1·84
	16	41·18	R.	I.	1 0 0·76	2·01	+1·25	−1·56	−0·31	S.	87 20 31·93	21·27	−10·66	+11·64	+0·98

Day, 1891.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Limb observed in R.A.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Limb observed in N.P.D.	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s			h m s	s	s	s	s		° ′ ″	″	″	″	″
Oct. 23	41·21	W.	II.	7 58 45·17	46·81	+1·64	−1·57	+0·07	S.	64 42 32·93	36·51	+ 3·58	− 3·29	+0·29
Nov. 9	41·28	W.	I.	21 46 15·85	17·25	+1·40	−1·60	−0·20	S.	109 1 66·77	59·26	− 7·51	+ 7·85	+0·34
11	41·29	F. B.	I.	23 38 13·76	15·09	+1·33	−1·51	−0·18	S.	97 32 34·31	25·02	− 9·29	+10·84	+1·55
13	41·29	R.	I.	1 27 40·28	41·42	+1·14	−1·54	−0·40	S.	83 57 46·35	35·88	−10·47	+11·23	+0·76
17	41·31	W.	II.	5 27 58·90	60·59	+1·69	−1·76	−0·07	N.	64 22 22·97	21·41	− 1·56	+ 3·30	+1·74
20	41·32	W.	II.	8 30 57·54	59·13	+1·59	−1·55	+0·04	S.	66 0 19·85	25·50	+ 5·65	− 4·59	+1·06
22	41·33	R.	II.	10 14 48·25	49·40	+1·15	−1·34	−0·19	S.	73 28 0·06	5·41	+ 5·35	− 7·54	−2·19
Dec. 8	41·39	R.	I.	23 19 52·59	53·85	+1·26	−1·49	−0·23	S.	99 39 39·82	29·88	− 9·94	+10·27	+0·33
11	41·41	R.	I.	1 59 28·79	29·99	+1·20	−1·52	−0·32	S.	80 9 57·21	46·41	−10·80	+10·47	−0·33
15	41·42	W.	II.	5 59 49·26	50·87	+1·61	−1·76	−0·15	N.	63 37 45·70	43·59	− 2·11	− 1·80	−0·31
16	41·43	R.	II.	7 3 0·30	1·83	+1·53	−1·72	−0·19	N.	63 25 44·88	46·58	+ 1·70	− 1·10	+0·60
17	41·43	F. B.	II.	8 3 43·44	44·95	+1·51	−1·63	−0·12	S.	64 53 22·58	27·90	+ 5·32	− 3·66	+1·66
18	41·43	W.	II.	9 0 33·91	35·44	+1·53	−1·52	+0·01	S.	67 44 3·89	11·39	+ 7·50	− 5·71	+1·79
20	41·44	R.	II.	10 41 56·02	57·23	+1·21	−1·32	−0·11	S.	76 14 39·28	46·42	+ 7·14	− 8·21	−1·07
22	41·45	W.	II.	12 11 54·33	55·55	+1·22	−1·22	0·00	S.	86 41 6·74	16·72	+ 9·98	− 9·13	+0·85
Mean of Errors, without regard to sign	...				...	**1·268**	...	**0·216**		...	...	**6·271**	...	**1·204**
Mean Errors for year	...	...	...		...	**+1·268**	...	**−0·197**						

Table II.

Radcliffe Observations of the Moon, 1891.

Errors of the Moon's Tabular Place in Longitude and Ecliptic Polar Distance, **Uncorrected** *and* **Corrected** *for the Change in the Unit of Mean Time introduced in the year 1864.*

Day, 1891.		Observer.	Limb observed in R.A.	Limb observed in N.P.D.	Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Errors of Longitude (Hansen *minus* Observed). Corrected.	Errors of E.N.P.D. (Hansen *minus* Observed). Uncorrected.	Errors of E.N.P.D. (Hansen *minus* Observed). Corrected.
Jan.	4	R.	II.	S.	+16″·37	−4″·94	+2″·60	+1″·08
	5	R.	II.	S.	+17·16	−4·82	+2·85	+1·02
Jan.	16	R.	I.	S.	+18·07	−5·11	−1·77	−0·58
	17	R.	I.	S.	+19·31	−3·13	−1·59	−0·05
	21	R.	I.	N. & S.	+18·87	−1·76	−2·13	−0·35
	22	W.	I.	N.	+18·55	−1·84	−0·79	+0·82
	24	R.	I. & II.	N.	+17·10	−3·02	−0·66	+0·45
	29	F.B.	II.	S.	+19·18	−0·87	−2·02	−2·76
Feb.	1	R.	II.	S.	+16·33	−4·82	+3·32	+1·70
Feb.	16	F.B.	I.	S.	+17·92	−3·51	−1·02	+0·86
	17	R.	I.	S.	+15·23	−5·53	−0·83	+1·03
	23	F.B.	II.	N.	+19·20	−0·69	+0·17	+0·25
	25	R.	II.	S.	+16·10	−4·06	+1·13	+0·49
	26	F.B.	II.	S.	+18·78	−1·33	+1·71	+0·70
	27	W.	II.	S.	+21·23	+0·90	+4·46	+3·16
Mar.	20	R.	I.	N.	+15·79	−4·22	−0·93	−0·10
	21	F.B.	I.	N.	+16·19	−3·68	−1·52	−1·05
	26	F.B.	II.	S.	+18·34	−2·15	+2·77	+1·48
	30	F.B.	II.	S.	+19·04	−2·83	+5·01	+3·09
Apr.	17	R.	I.	N.	+14·15	−5·98	−0·32	+0·32
	20	W.	I.	N.	+14·14	−6·01	−0·50	−1·07
	22	R.	I.	N.	+14·73	−5·89	+2·31	+1·05
	23	F.B.	I. & II.	N. & S.	+17·98	−2·98	+0·73	−0·79
	25	R.	II.	S.	+16·27	−5·34	+1·55	−0·39
May	15	R.	I.	N.	+13·89	−6·35	+0·13	+0·52
	16	F.B.	I.	N.	+16·45	−3·61	−1·45	−1·50
	19	R.	I.	N.	+14·82	−5·73	+1·10	−0·04
	31	R.	II.	N.	+23·12	−1·12	−2·17	−1·21
June	12	R.	I.	N.	+14·94	−5·38	+0·03	+0·17
	16	R.	I.	N.	+14·01	−6·59	+2·63	+1·31
	19	R.	I.	N.	+19·89	−2·26	+2·28	+0·27
	20	F.B.	I.	N. & S.	+22·08	−0·70	+2·00	−0·05
	25	F.B.	II.	N.	+27·37	+2·82	+0·97	+0·65

Day, 1891.		Observer.	Limb observed in R.A.	Limb observed in N.P.D.	Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Corrected.	Errors of N.P.D. (Hansen *minus* Observed). Uncorrected.	Corrected.
July	16	R.	I.	N.	+15″·14	−6″·48	+0″·30	−1″·63
	17	F.B.	I.	N.	+19·91	−2·35	+2·33	+0·31
	24	R.	II.	N.	+25·91	+0·90	−0·51	+0·17
	27	F.B.	II.	N.	+24·54	+0·95	−0·97	+0·86
Aug.	13	W.	I.	N.	+18·29	−3·25	+0·12	−1·80
	27	W.	II.	N.	+23·48	+1·61	−1·18	+0·53
Sept.	10	W.	I.	N.	+18·01	−3·45	+0·44	−1·43
	11	R.	I.	N.	+14·47	−7·67	+3·10	+1·30
	12	F.B.	I.	S.	+19·43	−3·49	−1·45	−3·06
	14	W.	I.	S.	+21·00	−3·72	+1·47	+0·59
	15	R.	I.	S.	+22·15	−3·40	−1·14	−1·45
	16	F.B.	I.	S.	+25·26	−0·71	−0·87	−0·57
	23	R.	II.	N.	+22·70	+0·14	−1·91	−0·09
Oct.	12	F.B.	I.	S.	+20·53	−3·74	+2·17	+1·70
	14	R.	I.	S.	+20·39	−5·26	−1·92	−1·22
	15	W.	I.	S.	+23·16	−2·94	−0·51	+0·73
	16	R.	I.	S.	+21·43	−4·67	−2·63	−0·88
	23	W.	II.	S.	+22·59	+0·99	−0·87	+0·10
Nov.	9	W.	I.	S.	+21·32	−2·80	−0·46	−0·62
	11	F.B.	I.	S.	+21·92	−3·08	−0·67	+0·36
	13	R.	I.	S.	+19·71	−5·83	−3·42	−1·50
	17	W.	II.	N.	+22·90	−1·04	−0·29	+1·68
	20	W.	II.	S.	+22·58	+0·79	+0·18	+0·89
	22	R.	II.	S.	+17·44	−3·35	−0·91	−1·07
Dec.	8	R.	I.	S.	+21·11	−3·27	−1·81	−1·03
	11	R.	I.	S.	+20·39	−4·33	−4·01	−1·94
	15	W.	II.	N.	+21·64	−2·02	−2·11	−0·31
	16	R.	II.	N.	+20·65	−2·47	−0·56	+0·87
	17	F.B.	II.	S.	+21·23	−1·26	+0·98	+1·96
	18	W.	II.	S.	+22·57	+0·64	+1·18	+1·68
	20	R.	II.	S.	+19·10	−1·90	−0·03	−0·39
	22	W.	II.	S.	+20·85	+0·34	+1·90	+0·78
Mean of Errors, without regard to sign		...	...	...	19″·298	3″·212	1″·505	0″·962
Mean Errors for Year		...	...	...	+19·298	−2·902	...	...

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F.B., Mr. F. A. Bellamy.

Table III.

Mean Excess over Observation of the Moon's Tabular Place in Longitude for the years 1847 to 1891, as computed from Hansen's Tables.

Uncorrected *and* **Corrected** *for the change in the Unit of Mean Time introduced in the year 1864.*

Year.	Errors of Longitude (Hansen *minus* Observed). Uncorrected.	Corrected.
	$''$	$''$
1847	+ 0·51	+0·51
1848	− 0·53	−0·53
1849	− 1·08	−1·08
1850	− 0·97	−0·97
1851	− 1·93	−1·93
1852	− 1·57	−1·57
1853	− 2·18	−2·18
1854	− 2·34	−2·34
1855	− 1·40	−1·40
1856	− 1·51	−1·51
1857	− 2·41	−2·41
1858	− 2·61	−2·61
1859	− 2·49	−2·49
1860	− 3·62	−3·62
1861	− 2·95	−2·95
1862	− 2·83	−2·83
1863	− 1·61	−1·61
1864	+ 0·12	−0·81
1865	+ 1·27	−0·22
1866	+ 2·14	−0·22
1867	+ 3·48	+0·36
1868	+ 4·12	+0·28
1869	+ 4·28	−0·35
1870	+ 4·83	−0·66
1871	+ 6·96	+0·44
1872	+ 7·31	+0·10
1873	+ 8·24	+0·20
1874	+ 9·29	+0·56
1875	+ 9·87	+0·36
1876	+ 9·80	−0·50
1877	+ 9·23	−1·90
1878	+ 8·22	−3·60
1879	+ 9·63	−3·12
1880	+10·89	−2·77
1881	+10·51	−4·06
1882	+12·68	−2·51
1883	+14·71	−1·50
1884	+14·65	−1·91
1885	+15·20	−1·82
1886	+15·34	−2·53
1887	+15·70	−3·25
1888	+17·68	−2·46
1889	+17·37	−3·51
1890	+18·02	−3·55
1891	+19·30	−2·90

1847 to 1879: Greenwich observations. 1880 to 1882: Mean of Greenwich and Radcliffe. 1883 to 1891: Radcliffe observations.

Radcliffe Observatory, Oxford:
1892 *May* 13.

Note on the Secular Perturbations of the Earth by Mars.
By R. T. A. Innes.

In my computation, printed in this volume on pages 80 to 87, I do not find for $\left[\frac{dp}{dt}\right]_{00}$ and $\left[\frac{dq}{dt}\right]_{00}$ the values given by Le Verrier in *Mémoires de l'Observatoire de Paris*, tome ii. Mr. Asaph Hall, Jun., has also performed the calculation by Gauss's method,* and finds for these functions practically the same values as computed by Professor Hill by algebraical expansion.† I therefore revised my figures, and not finding any material difference I examined the formulæ given in vol. i. of the *Astronomical Papers of the American Ephemeris*, with the result that I found a misprint in the value of J_3 on pages 338 and 359. For sin Π read sin Π'. My figures, altered accordingly, make J_3 so nearly the value found by Mr. Hall that it is needless to finish the calculation.

It will be interesting to compare the values of the secular perturbations of the Earth caused by *Mars* found by Le Verrier and Professor Hill by expansion with those found by Gauss's method by Mr. Hall and myself. Reducing all to the mass of *Mars* used by Mr. Hall, viz. $\frac{1}{m'} = 3093500$, we have—

$\left[\frac{de}{dt}\right]_{00}$	$-0''.015723$ Hall.	$\left[\frac{d\varpi}{dt}\right]_{00}$	$+0''.975139$ Hall.
	-0.015734 Le Verrier.		$+0.975430$ Le Verrier.
	-0.015722 Innes.		$+0.975224$ Innes.
$\left[\frac{dp}{dt}\right]_{00}$	$+0.006344$ Hall.	$\left[\frac{dq}{dt}\right]_{00}$	-0.007195 Hall.
	$+0.006336$ Hill.		-0.007211 Hill.
	$+0.006351$ Le Verrier.		-0.007209 Le Verrier.

$\left[\frac{dL}{dt}\right]_{00}$	$0''.23424$ Hall.
	0.23368 Le Verrier.
	0.23469 Innes.

Erratum in my previous communication:—

$$\text{Page 81, read } \nu' = \frac{\sqrt{3}}{32\, m_{,}^{2}}\left\{1 + 2\frac{\lambda^4}{m_{,}^{2} m_{,,}^{2}} + 4\frac{\lambda^{12}}{m_{,}^{4} m_{,,}^{4} m_{,,,}^{2}} + \&c.\right\}$$

There are a few other misprints, but they are of no importance.

The second part of the expression for J_3 on page 81, and J_3 and $\frac{a}{r}W_0$ on page 85, are incorrect for the reason pointed out above.

* *Astronomical Journal*, vol. xi., No. 4, July 24, 1891.
† *Astronomical Papers of the American Ephemeris*, vol. iv., pp. 511–12.

Sydney: 1892 *March* 7.

On a New Form of Altazimuth. By W. H. M. Christie, M.A., F.R.S., Astronomer Royal.

The altazimuth proposed is a reversible transit-circle with iron stand, capable of being placed in different definite azimuths, say 0°, 20°, 40°, 60°, 75°, 90° E. or W. of the meridian, the instrument being used as a transit-circle in any one of these azimuths. This may be arranged by mounting the iron supports of the transit-circle on a circular base resting at three parts of its circumference on a circular casting carefully planed on its upper surface and bolted to the foundation pier. By the help of friction rollers, brought into action to take off part of the weight, the transit-circle could be rotated round a central pivot from one definite azimuth to another, suitable arrangements being made for locking it firmly in the required position, as in the case of a railway turntable. In fact, the transit-circle would be mounted on a turntable with provision for bringing it into definite azimuths and for securing its fixity when brought into position. The proposed altazimuth would thus be essentially a transit-circle capable of being used out of the meridian, in the prime vertical or in any other selected azimuthal plane. It would differ in principle from the well-known form of transit-instrument in the prime vertical, as the zenith-distance of the object would be observed (by means of the vertical circle) as well as the time of azimuthal transit, and a complete determination of the position of the object (R.A. as well as N.P.D.) would be made by a method of observation and reduction essentially different, and applicable in any azimuthal plane.

The principle of the method of observing would be that the observations of azimuth and zenith-distance should be referred to the same instant of time and that from these the R.A. and N.P.D. would be deduced subject to corrections for the instrumental errors of collimation, level and azimuth (difference from assumed azimuth).* The computations would thus be greatly simplified, and tables could be readily formed for the given azimuths of auxiliary quantities which would render the reductions very easy.

Transits should be taken over vertical wires (say two sets of five, omitting the central wire), and over horizontal wires (say two sets of five, omitting the central wire) arranged so that, generally, the horizontal and vertical transits would not interfere with each other, and that the mean of the time of transits over the vertical and horizontal wires respectively would differ only by a small quantity. This condition may be secured by having in addition to the systems of vertical and horizontal wires (each carried on a micrometer slide as usual in a transit-circle) a wire

* The observed Z.D. and time of transit might be corrected for the effect of errors of collimation and level before the computation of N.P.D. and R.A., but the corrections would, I believe, involve a little more labour.

carried by a position-circle micrometer, which would be set to the approximate inclination of the path of the object to be observed. The telescope having been set to the computed Z.D. and clamped, when the object enters the field it is to be bisected (approximately, with allowance for curvature of path if necessary) by the position-circle wire by means of its micrometer screw, or by the slow motion in Z.D., and the middle horizontal wire is to be made to bisect this wire at its intersection with the middle vertical wire by means of the Z.D. micrometer. The object should thus transit simultaneously over the middle horizontal and vertical wires and the means of the times of transit over the two sets of wires would not differ by more than a very small quantity, say δt.

[As an alternative method of observing the Z.D., the object might be bisected by the wire of the position micrometer (set to the approximate position angle of the diurnal path) at its transit over the middle and pairs of vertical wires, as in zenith-distance observations with a meridian transit-circle.]

Let t, $t+\delta t$ be means of times of transit over the vertical and horizontal wires respectively, z' the observed zenith distance (corrected for refraction and parallax), $z = z' - \delta z$ the Z.D. at time t.

A the assumed azimuth (not greater than 90°, and reckoned positive from South towards West), γ the co-latitude, h the hour angle (in arc), Δ the N.P.D., and S the parallactic angle.

Then we have,

$$\delta z = 15 \sin S \sin \Delta \delta t = 15 \sin \gamma \sin A \, \delta t = 15 m \, \delta t$$

where

$$m = \sin \gamma \sin A, \text{ a constant for a given azimuth,}$$

whence

$$z = z' - \delta z \text{ is known.}$$

Therefore, putting

$$\tan \theta = \tan \gamma \cos A,$$

and

$$n = \frac{\cos \gamma}{\cos \theta}$$

where θ and n are constants

$$\cos \Delta = \frac{\cos \gamma \cos (z+\theta)}{\cos \theta} = n \cos (z+\theta) \qquad (1)$$

$$\sin h = \frac{\sin A \, . \, \sin z}{\sin \Delta} \qquad (2)$$

which give the N.P.D. and hour angle, uncorrected for instrumental errors. Also the parallactic angle is given by

$$\sin S = \frac{\sin \gamma \sin A}{\sin \Delta} = m \operatorname{cosec} \Delta.$$

It has been assumed so far that the object was observed at the assumed azimuth A at time t, and corrections for errors of

collimation (c), level (l), and azimuth (a), must now be applied to Δ and h viz. :—

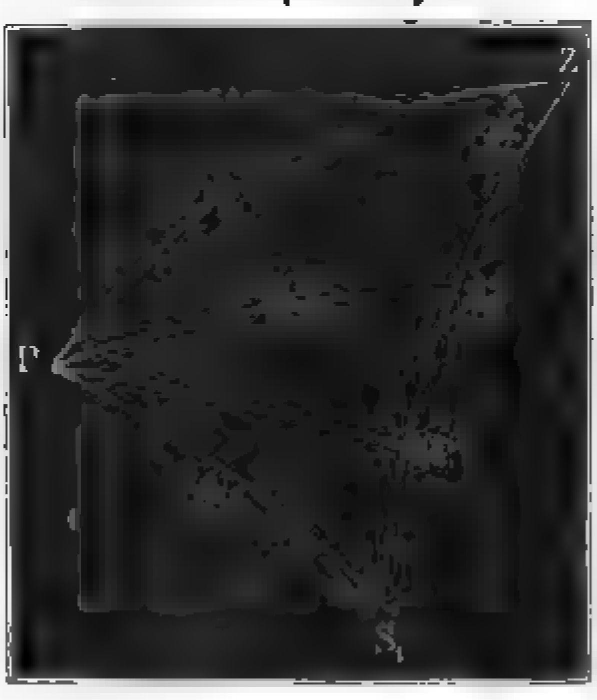
Collimation	$\delta\Delta = c \sin S$	$\delta h = c \cos S \operatorname{cosec} \Delta$
Level	$\delta'\Delta = l \cos z \sin S$	$\delta' h = l \cos z \cos S \operatorname{cosec} \Delta$
Azimuth	$\delta''\Delta = a \sin z \sin S$	$\delta'' h = a \sin z \cos S \operatorname{cosec} \Delta$

The factors sin S, cos z sin S, sin z sin S, cos S cosec Δ, cos z cos S cosec Δ, sin z cos S cosec Δ may be tabulated to three places of decimals for the given azimuths, and at convenient intervals of Z.D. or N.P.D., but probably only two places of decimals would be required in most cases, so that the corrections would be very easily made.

Thus the N.P.D. and hour angle are determined, and from the latter in combination with the time of transit the R.A. of the object is at once obtained if the clock error is known. Reciprocally, the clock error would be found from observations of clock stars, the R.A. of which is known.

It remains to consider the determination of the zenith point and of the errors of collimation, level, and azimuth.

The zenith point would be usually determined by the nadir observation of the middle Z.D. wire reflected in a mercury trough. In the meridian it would also be found from reflection observations of stars and the R—D correction deduced. The collimation error would be determined by the nadir observation of the reflected azimuth wire in reversed positions of the transit-circle. This would be checked by observations of collimators in the meridian, and also, perhaps, in the prime vertical, the collimators being mounted on either of two pairs of piers, in the meridian and prime vertical respectively.



The level error would be found by reflection from mercury (nadir observation). The azimuth may be determined by two observations of a circumpolar star, the co-latitude γ being

known. Thus, if P,Z in the figure be the pole and the zenith, S_1 S_2 the two positions of a circumpolar star when it is in azimuth $A' = A + a$, PM an arc perpendicular to ZS_2S_1 and bisecting S_1S_2 in M, the Z.D. z, at sidereal time t_1 (corresponding to S_1) and the Z.D. z_2 at sidereal time t_2 (corresponding to S_2) are observed, the observations being corrected for collimation and level and also, if necessary, for change of R.A. and N.P.D. in the interval $t_2 - t_1$.

Then

$$S_1PM = S_2PM = \frac{15}{2}(t_2 - t_1)$$

$$S_1M = S_2M = \frac{1}{2}(z_1 - z_2),$$

and the azimuth $A' = A + a$ is given by

$$\cos A' = \tan \tfrac{1}{2}(z_1 + z_2) \cot \gamma.$$

The N.P.D. and R.A. of the star are given by

$$\sin \Delta = \sin \tfrac{1}{2}(z_1 - z_2) \operatorname{cosec} \frac{15}{2}(t_2 - t_1)$$

$$\sin h_1 = \frac{\sin A' \sin z_1}{\sin \Delta}, \quad \sin h_2 = \frac{\sin A' \sin z_2}{\sin \Delta},$$

whence the R.A. α is

$$\alpha = t_1 + \frac{h_1}{15} \text{ or } t_2 + \frac{h_2}{15},$$

This method of determination of azimuth error (as well as of R.A. and N.P.D. of the star) is merely indicated above in general terms, without entering into details of computation.

The azimuth may, if necessary, be found from a single observation of a star if the N.P.D. and the co-latitude are known, or if the hour angle and star's N.P.D. or the co-latitude are known.

In cases where the motion in azimuth or zenith-distance is very slow, the azimuth or Z.D. micrometer may be used to bisect the star (with the middle wire), the instant of bisection being recorded on the chronograph, as in the case of close circumpolar stars with the transit-circle.

It will be seen from the foregoing explanation that such an instrument would be available to determine the R.A. and N.P.D. of the Sun, Moon, planets, and stars out of the meridian with the same accuracy as for a meridian observation, and with little more labour in calculation. The importance of extra meridian observations of the Moon was urged long ago by Sir G. B. Airy and has been generally recognised, and similar observations of the planets would also be of great value for the same reason, viz., the determination of positions in parts of the orbit where daylight prevents the observation of the object on the meridian or where the meridian observation would be some time after midnight, involving a long watch for the observer. The planet *Mercury* may be specially mentioned as an object for observation

out of the meridian, owing to the paucity of meridian observations.

The proposed instrument would also be available for the determination of refraction, latitude, and systematic errors of N.P.D. by comparison of observations of stars and the Sun in different azimuths, and this would, in my view, be a very important application of the instrument. It would, in fact, enable us to determine with the accuracy of a meridian observation the fundamental places of stars under different instrumental and observational conditions, and thus to give independent determinations available for the discussion of refraction, latitude, and systematic errors generally.

When fixed in the meridian, this instrument would be to all intents and purposes a transit-circle, and could be used for all the ordinary meridian observations. I would propose that it should have a telescope of 8 inches aperture and of about 8 feet focal length, with two circles of 3 feet diameter each read by four microscopes, and that the reversing apparatus should lift it sufficiently high to give a clear view for the collimators, without perforation of the central portion, which should be made barrel-shaped, instead of in the usual form of a cube. The object-end and eye-end of the telescope tube should be precisely similar as regards strengthening diaphragms, and the object-glass and eye-piece micrometer should be readily interchangeable, the mode of attachment to the tube being the same for both.

Royal Observatory, Greenwich:
1892 May 12.

Note on the History of the Great Sun-spot of 1892 *February.* By E. W. Maunder.

(*Communicated by the Astronomer Royal.*)

Although it was not until the month of 1892 February that this Sun-spot first attracted general attention, this was not its first appearance, for it had been seen during the three preceding months. It was first seen so far back as 1891 November 15, and was not finally lost to sight until 1892 March 17. And as it took its first rise, and underwent final dissipation, whilst in the invisible hemisphere, it was thus watched through the whole of five semi-rotations.

It was only during the February appearance that the group reached exceptional proportions, but during each of the other four appearances it was an important group, and during November it was decidedly above the average of spots at the present time as to size, and showed many features of interest. But the most remarkable feature in its history was the striking and persistent drift in latitude which it exhibited from its first appearance in 1891 November up to the time of its greatest

development in 1892 February. The following measures are complete at present only for the months of 1891 November and December. As no photographs for 1892 have been received as yet from the Solar Physics Committee, and 1892 January and February were very cloudy, the Greenwich record is very defective during those two months. Photographs were only obtained on seven days during the January appearance of the group, on six days during the period of its observation in February, and on ten days during that in March. The results, though thus imperfect, will be sufficient to render obvious this most unusual movement.

1891 *November*.

The group was seen on thirteen days during this month, and on each day one or more photographs were taken either at Greenwich or at one of the two co-operating observatories, Dehra Dûn and Mauritius.

November 15. A large spot, about 400 millionths in area, is seen close to the east limb.

November 16. The group now consists of three spots: two nearly in the same longitude, but differing in latitude, the third following the other two by about 5° of longitude.

November 17. The two preceding spots of November 16 now appear to be coalescing. A few faint spots and an arch of bright faculæ unite these preceding spots to the one which follows.

November 18. The group has now assumed the form, so typical of the more important disturbances, of a long procession of spots of various sizes, of which the first and last are by far the most considerable.

November 19. Usually in such cases the leading spot becomes very sharply defined and nearly circular in shape, and this takes place eventually in the case of the leader of the present group, but it passes through some curious changes first. On this day it shows itself as a large and most beautiful spot, as it is intersected by an intricate network of bright bridges.

November 20. The leader seems to show a tendency to assume a symmetrical shape, but it is strongly elliptical, instead of being circular.

November 21. The small spots in the middle of the group have nearly all disappeared, whilst both the leading and the last spots have greatly increased in size; the leader lengthening out instead of tending to become more nearly circular.

November 22. The group now consists simply of two great spots; the leader very much elongated and intricate in shape; the following spot nearly circular and with very dark nucleus. The remarkable changes which the entire group underwent on these days were accompanied by a considerable magnetic disturbance; the needles showing a moderate amount of agitation from November $19^d\ 23^h$ (Greenwich Civil Time) to November $21^d\ 0^h$, and again after a short period of quiescence, from November $21^d\ 6^h$ until November $22^d\ 2^h$.

November 23. The group now begins to decline, the leading spot breaking up into a long chain of small spots, of which the leader, which is nearly circular in shape, is the best defined.

November 24. Of this chain of small spots, few except the leader now remain. The leader, however, has become larger and better defined, with a dark central umbra.

November 25. The group is again practically reduced to two spots, the smaller and fainter spots in the middle of the group having nearly all disappeared.

November 26. Only two spots now remain, and these are nearly of equal size. For the following spot of November 22 has been gradually diminishing in area whilst the preceding part of the group has been undergoing these remarkable changes.

November 27. The leader is now only seen as a shallow notch on the limb, too faint and shallow for accurate measurement, so that to a cursory view the following spot appears to be left alone.

The group was seen on the East limb on November 15, passed the central meridian on November $21^d\ 13\frac{1}{2}^h$ (Greenwich Civil Time), and reached the West limb on November 27.

Two small groups attended the great one during part of its course. Both were so near the great group as evidently to belong to the same general disturbance, and indeed the great spot of February was large enough to have included all the three groups of November within its area. Calling the group, the history of which we have just followed out, A, and these two minor groups B and C, the following notes briefly sum up their history.

Group B.

Appeared on November 15 as a scarcely perceptible pore, but was not seen on November 16. Reappeared on November 17, in advance of Group A in longitude, and on nearly the same

parallel of latitude. It was only a small and insignificant group during this rotation, but was seen also during December.

Group C.

First seen on November 20 as a fairly important group. It had nearly the same longitude as Group A, but was considerably nearer the equator. It shared in the great change of Group A on November 22 and 23. For whilst on November 22 Group C had all but disappeared, on November 23 it was seen as a chain of small spots completely enclosing a large rhomboidal area, greater than the largest spot of Group A. By November 24 Group C had taken the typical form of a chain of small spots, the leader of which was the largest, and the most regular in form, whilst the following members of the group were quite faint and small.

The following tables give the mean heliographic positions of the centres of the groups during their successive appearances, together with their areas, as projected, and as corrected for foreshortening, the former being expressed in millionths of the Sun's apparent disc, the latter in millionths of the visible hemisphere.

Group A, 1891 November.

Date. Greenwich Civil Time.				Longitude from Central Meridian.	Heliographic Longitude from Prime Meridian.	Latitude.	Projected Area. Umbra.	Projected Area. Whole Spot.	Area corrected for foreshortening. Umbra.	Area corrected for foreshortening. Whole Spot.
		h	m	s	°	°	°			
Nov. 15	3	9		−84·1	260·9	−16·8	0	66	0	401
16	4	19		−69·0	262·2	−17·2	28	175	41	267
17	5	44		−55·2	262·1	−17·9	58	321	56	305
18	5	14		−44·0	260·3	−18·5	56	421	42	318
19	7	20		−28·4	261·7	−18·9	141	817	88	493
20	4	39		−17·6	260·7	−19·2	276	1369	156	773
21	4	23		− 5·0	260·2	−19·4	327	1898	178	1029
22	6	49		+ 9·5	260·3	−20·1	308	2115	171	1162
23	4	33		+20·9	259·7	−20·1	270	1564	160	909
24	5	14		+36·9	262·1	−20·9	208	1074	141	733
25	10	23		+50·9	262·1	−20·5	70	1002	154	908
26	11	35		+65·7	261·0	−20·1	63	456	81	609
27	5	32		+78·7	264·2	−20·4	46	252	72	719
Means				...	260·7	−19·1	...	...	103	634

Group B, 1891 *November*.

	h m s	°	°	°				
Nov. 15	3 9	−58·7	287·3	−20·1	0	2	0	2
16	4 19	...	...	...	...	...	...	...
17	5 44	−32·9	284·4	−18·4	0	11	0	7
18	5 14	−19·5	284·8	−18·9	4	48	2	27
19	7 20	− 8·1	282·0	−19·3	13	45	7	25
20	4 49	+ 6·6	284·9	−19·1	35	115	19	62
21	4 23	+18·2	283·4	−19·0	10	77	6	44
22	6 49	+34·9	285·7	−18·2	0	96	0	59
23	4 33	+45·5	284·3	−18·4	3	57	3	44
24	5 14	+63·0	288·2	−18·5	0	16	0	18
Means		...	285·0	−18·8	...	...	4	32

Group C, 1891 *November*.

	h m s	°	°	°				
Nov. 20	4 49	−16·8	261·5	−11·4	22	120	13	65
21	4 23	− 4·0	261·2	−12·0	0	30	0	15
22	6 49	+13·2	264·0	−11·9	0	41	0	21
23	4 33	+24·4	263·2	−10·9	27	170	15	96
24	5 14	+39·0	264·2	−11·1	46	315	30	207
25	10 23	+57·7	266·9	−10·5	26	182	25	175
26	11 35	+72·6	267·9	−10·7	12	57	20	96
27	5 32	+83·4	268·9	−10·6	0	53	0	244
Means		...	264·7	−11·1	...	...	13	115

1891 *December*.

Group A was first seen on December 12, crossed the central meridian on December $18^{d}\ 7^{h}$, and reached the West limb on December 24. Its history during this appearance is soon told. It was a single well-defined circular spot, and it suffered very little change throughout the entire rotation.

Group B was not seen on December 12. It had not therefore persisted during the entire interval from its reaching the West limb on November 24, for had it done so it would have been seen on the East limb on December 11. But it soon formed again, and a very small spot was seen on December 13, two spots on December 15, and by December 16 the total area of the groups equalled that of the single spot which now represented Group A. On this day it showed a cluster of small spots in the preceding part of the group, and a large spot with a very dark umbra in the following part. The group had greatly increased in area by December 17, and from this time to the end of the rotation it was much larger than Group A. For the greater part of this period

it consisted chiefly of two circular spots, either of which was larger than the spot which made up Group A.

Group C did not reappear in this rotation, but was represented on December 12 by a bright group of faculæ.

Group A, 1891 *December*.

Date. Greenwich Civil Time.				Longitude from Central Meridian.	Heliographic Longitude from Prime Meridian.	Latitude.	Projected Area. Umbra.	Projected Area. Whole Spot.	Area corrected for foreshortening. Umbra.	Area corrected for foreshortening. Whole Spot.
		h	m s	°	°	°				
Dec.	12	5	15	−80·1	267·9	−19·8	11	45	32	135
	13	5	36	−67·7	266·9	−19·7	18	107	25	147
	14	7	39	−52·2	268·2	−18·9	31	146	27	127
	15	5	3	−40·9	267·7	−20·0	38	194	27	136
	16	4	50	−27·8	267·7	−20·0	41	200	25	120
	17	11	59	−11·1	267·3	−19·3	36	276	19	148
	18	4	43	− 1·3	267·9	−20·2	49	245	26	130
	19	9	35	+14·7	268·1	−19·9	33	215	18	117
	20	5	23	+28·5	267·5	−19·7	25	162	15	98
	21	11	45	+41·8	267·7	−19·4	12	148	8	103
	22	7	18	+52·7	267·9	−20·0	16	138	14	120
	23	7	11	+63·7	265·8	−18·1	19	77	23	95
	24	5	18	+77·6	267·5	−19·8	9	37	20	86
Means				...	267·5	−19·6	...	...	21	120

Group B, 1891 *December*.

Date.		h	m s	Longitude from Central Meridian.	Heliographic Longitude from Prime Meridian.	Latitude.	Projected Area. Umbra.	Projected Area. Whole Spot.	Area corrected for foreshortening. Umbra.	Area corrected for foreshortening. Whole Spot.
Dec.	13	5	36	−48·2	286·4	−18·6	0	13	0	11
	14	7	39	−36·0	284·4	−17·7	0	3	0	2
	15	5	3	−24·8	283·8	−20·1	0	47	0	28
	16	4	50	−12·1	283·4	−20·0	56	200	28	99
	17	11	59	+ 5·8	284·2	−19·1	134	715	71	376
	18	4	43	+15·5	284·7	−19·8	161	742	88	408
	19	9	35	+31·2	285·0	−19·2	117	871	72	534
	20	5	23	+45·4	284·4	−18·7	46	548	33	404
	21	11	45	+58·5	284·4	−18·3	39	394	39	390
	22	7	18	+69·2	284·0	−19·0	20	218	27	315
	23	7	11	+79·3	281·4	−18·2	12	52	35	157
Means				...	284·2	−18·9	...	...	36	248

1892 *January*.

The sun was photographed on only seven days at Greenwich during the January appearance of the group, and as no

photographs have as yet been received through the Solar Physics Committee from India or Mauritius, the daily record is still very incomplete. The group would appear to have crossed the central meridian on January 13^d 19^h, and to have reached the West limb on January 21.

It is not quite clear whether the group represented Group A or Group B, or whether it represented rather the general disturbance of which those two groups were indications. There can be no doubt but that A and B both belong to the same general disturbance, but if the January group represented one of the two rather than the other, it will probably have corresponded to Group B, inasmuch as it was moving in the direction of decreasing longitude throughout January, and its longitude was greater than that of A, but less than that of B.

The group on January 7 consists of a single large, well-defined spot. On January 8, when it has come further on the disc, some faint smaller spots are seen following it, and a small spot is seen to the north which appears to correspond to the Group C of the November appearance. By January 12 these faint companions of the principal spot have nearly disappeared, and on January 13, 14, and 16 the principal spot was seen alone. But a very striking change had occurred by January 20, for on that day the group consists of two large, well-defined spots, with a number of small spots connecting them. The imperfection of the record, owing to cloudy weather on January 17, 18, and 19, renders it impossible to say at present when and how this change took place.

Group B, 1892 January.

Date. Greenwich Civil Time.	Longitude from Central Meridian.	Heliographic Longitude from Prime Meridian.	Latitude.	Projected Area. Umbra.	Projected Area. Whole Spot.	Area corrected for foreshortening. Umbra.	Area corrected for foreshortening. Whole Spot.
h m s	°	°	°				
Jan. 7 9 44	−81·2	281·0	−24·7	0	50	0	144
8 10 26	−67·4	282·1	−24·6	33	172	45	229
12 9 38	−18·5	278·8	−24·7	36	331	36	191
13 10 6	− 4·8	279·1	−24·5	41	347	22	185
14 9 37	+ 8·0	278·9	−25·3	49	387	26	207
16 11 49	+34·1	277·5	−25·7	30	296	19	189
20 11 30	+77·0	267·9	−25·5	112	683	205	1404
Means	...	278·0	−25·0	...	...	50	364

1892 *February.*

Photographs were taken at Greenwich only on six days during the February appearance of the great group. On February 4 the first outliers of the group made their appearance at the East limb. On February 5 the great spot itself was seen. A period of cloudy weather then set in, and the next photograph was not taken till February 13. The group was then seen in its

full magnificence as the largest ever photographed since the beginning of the Greenwich record. The extreme length of the group was 25° of solar longitude, and that of the great spot 14°; the greatest breadth of the entire group was 10° of solar latitude and of the spot 8°. A very considerable group, apparently corresponding to group C, lay a little to the north. The great group much resembled in its chief characteristics the great groups of April and November, 1882. Instead of a number of spots tending to stretch themselves out into a long line, and the principal members of which tend to assume the circular form, which is the arrangement typical of most considerable groups, these three great groups showed each one great irregular spot in the centre of the group, in contradistinction to the more general type, in which the chief spots are found either at the beginning or end of the group. Then these great spots each contained a number of distinct nuclei within their borders, nuclei wholly and entirely separate from each other, and not merely fragments of one nucleus cut up in appearance only by overlying bright bridges. No important change in character was noted during the succeeding days, though there was a marked diminution in area. Group C was of the usual type—a chain of spots of which the first and last were the most considerable. The spots in the middle of the group tended to die out as usual, the only departure from the normal behaviour being that in the course of events both the first and last spots were provided with a considerable companion, and the group reached the limb as a pair of close pairs. The Great Group crossed the central meridian, February $12^{d}\ 2^{h}$.

Group B, 1892 February.

Date. Greenwich Civil Time.	Longitude from Central Meridian.	Heliographic Longitude from Prime Meridian.	Latitude.	Projected Area. Umbra.	Projected Area. Whole Spot.	Area corrected for foreshortening. Umbra.	Area corrected for foreshortening. Whole Spot.
h m s	°	°	°				
Feb. 4 10 49	−88·4	264·4	−26·4	0	25	0	250
5 10 25	−81·6	259·3	−28·8	77	1144	96	1524
13 9 47	+17·3	253·1	−27·3	952	6274	536	3528
16 9 40	+56·2	252·6	−26·5	331	2919	300	2670
17 12 10	+69·0	250·9	−27·4	122	1249	161	1683
18 11 58	+80·8	249·6	−28·8	35	635	98	1605
Means	...	255·0	−27·5	...	...	198	1877

Group C, 1892 February.

Date.	Longitude from Central Meridian.	Heliographic Longitude.	Latitude.	Projected Umbra.	Projected Whole Spot.	Corrected Umbra.	Corrected Whole Spot.
Feb. 13 9 47	+ 3·7	239·5	−19·4	164	1022	85	529
16 9 40	+42·0	238·4	−19·6	66	559	44	382
17 12 10	+57·1	239·0	−20·1	24	274	22	250
18 11 58	+69·5	238·3	−20·1	6	159	14	216
Means	...	238·8	−19·8	...	...	41	344

1892 *March.*

Photographs were taken at Greenwich on ten days during this appearance, the group being first seen on the East limb on March 4. It had undergone a very great diminution in size since February, its area on March 4 being only 158 millionths, as against the 3528 millionths of February 13. It, however, steadily increased in size till it reached the central meridian on March $10^d\ 10^h$, small spots forming both in advance and behind the principal spot, and tending to coalesce with it. By March 12 the group consisted of a large spot followed by a train of small faint spots. By March 14 the leader showed signs of dividing into two nearly equal portions, and by March 16 the division had been completely accomplished. It is interesting to note that Group C appeared to be represented on March 16 by a pair of small spots, though no spots were visible in that region during the earlier part of the rotation.

Group B, 1892 *March.*

Date. Greenwich Civil Time.	Longitude from Central Meridian.	Heliographic Longitude from Prime Meridian.	Latitude.	Projected Area. Umbra.	Projected Area. Whole Spot.	Area corrected for foreshortening. Umbra.	Area corrected for foreshortening. Whole Spot.
h m s	°	°	°				
Mar. 4 11 30	−84·6	249·9	−28·8	0	44	0	158
5 9 51	−70·3	249·0	−28·5	20	147	28	208
7 9 54	−45·6	247·2	−28·5	46	716	34	813
8 10 39	−28·9	250·4	−29·0	57	856	35	521
10 11 48	+ 1·1	253·4	−27·7	163	1192	87	640
11 9 22	+10·0	250·4	−28·9	80	639	45	358
12 11 9	+24·8	251·1	−28·1	99	8 2	60	475
14 10 13	+51·7	252·2	−28·3	53	350	45	293
16 11 4	+75·2	248·8	−27·7	44	243	44	243
17 11 2	+87·6	247·4	−28·4	5	37	24	178
Means	...	250·0	−28·4	...	...	40	389

Group C, 1892 *March.*

Mar. 16 11 4	+63·5	237·1	−23·4	0	27	0	30
17 11 2	+76·5	236·9	−23·8	3	32	5	61
Means	...	237·0	−23·6	...	...	3	46

It may be interesting to add that though the great group did not return again, yet that during April a circular spot was seen in about the same longitude and in the same latitude as that in which group C had originally appeared, so far back as 1891 November. Later still a very considerable group has been seen

during the last days of April, and the early days of May, in almost exactly the latitude occupied by the great group during the January appearance, and in almost the same longitude as it occupied in March, whilst an examination of earlier photographs in 1891 has shown two evanescent little groups on September 27 and October 25, in the precise region which was the seat of the first appearance of the group in November last. The entire region, therefore, has been the seat of strong, intermittent, and repeated disturbance.

On a Pretended Early Discovery of a Satellite of Mars.
By Ralph Copeland, Ph.D.

In the Crawford Library of the Edinburgh Royal Observatory is a quarto pamphlet of ten leaves, the complete title of which is: "Eberhard Christian Kindermanns, Königl. Pohl. und Churfürstl. Sächszl. Hof-*Math.* und *Astronomi*, ASTRONOMISCHE BESCHREIBUNG und NACHRICHT von dem COMETEN 1746. Und denen noch kommenden, welche in denen innen besagten Jahren erscheinen werden.—Dreszden, zu finden bey Gottlob Christian Hilschern, Hof-Buchhändler, 1746." Although Kindermann* thus held the post of astronomer to the King of Poland, who was at the same time Electoral-Prince of Saxony, the few observations he has placed on record have hitherto proved of very little value. Doubts, indeed, have at various times been expressed as to their general trustworthiness; nor is it quite certain that the comet of which the little book under consideration professes to treat ever really existed, although Kindermann gives the names of two persons and mentions a third by whom he alleges it to have been seen, as well as by himself. Dr. Hind, however, has succeeded in deriving a rough orbit from the fuller particulars given by Struyck, to whom Kindermann had communicated them. The tract also contains predictions of the return of three several comets, amongst them that of 1661, of which the elements, computed long previously by Halley, resemble those of the comet of 1532. Probably it was this resemblance which led Kindermann to assume their identity with a period of 129 years and a consequent return in 1790, a conjecture which, it is needless to say, was never realised.

These particulars are now of little moment, except in so far as they characterise the writer of the book, the frontispiece of which is sufficiently striking, containing, as it does, a little figure professing to show the orbit of a satellite of *Mars* discovered by the author. The encircling legend runs: "Via Luna (*sic*) Martis entdecket vom Autore den 10. Iul: 1744." On

* The Pulkowa Library contains three of his books, including the one described above.

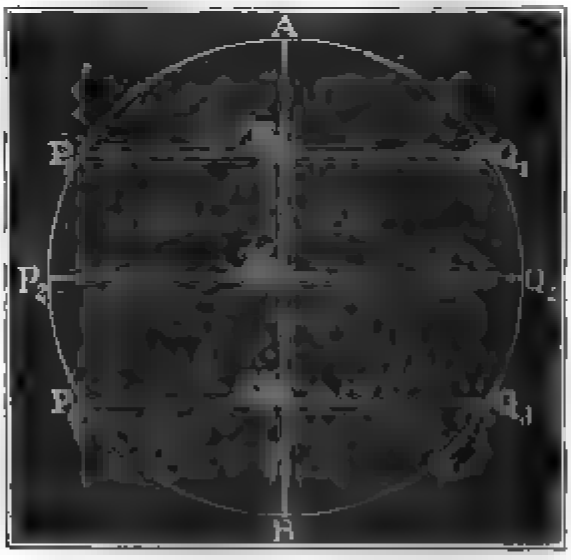
the face of the planet are various distinct markings, amongst which it is easy to recognise the long "dumb-bell," drawn by Divini and Cassini, and figured in the first volume of the *Philosophical Transactions.* The satellite is only removed about $2\frac{1}{2}$ radii of *Mars* from the centre of the planet. The satellite is nearly four-tenths of the diameter of the primary, and both bodies are liberally provided with atmospheres.

It may be mentioned that *Gulliver's Travels* were given to the world in 1726–7, while Voltaire's *Micromégas* seems to have been published about 1752. The statements they contain about the moons of *Mars* are widely known through Professor Hall's memoir. Kindermann's "discovery" is thus intermediate, in point of date, between the felicitous conceptions of the great satirists.

On the Illumination of Saturn's Rings during Sunrise; and on recent Observations of their Reappearance. By the Rev. A. Freeman.

In order to ascertain the significance of the American and European observations made in 1891 October and November, near the time when the Sun's centre was in the plane of *Saturn's* Rings, I have investigated expressions for the intensity of light cast by the Sun upon the rings, at the four stages when, to an observer at *Saturn's* centre, one-fourth, one-half, three-quarters, and the whole of the Sun's diameter has risen above the plane of the rings. Adopting the method given by Sir J. Herschel in the article on *Light* (*Encyc. Metrop.* § 44 sqq.) or in Parkinson's *Optics*, § 42; if with vertex at the centre of the rings, we draw a cone whose generators touch the spherical surface of the Sun, and consider the boundaries of the section of a hemisphere radius unity, concentric with the rings, intercepted between the cone and the plane of the rings; and if we project this intercepted surface orthogonally upon the plane of the rings, we have an exact representation of the intensity of Sun-light received upon unit area at the centre of the ring-plane. Moreover, if 2θ be the circular measure of the apparent diameter of the Sun as seen from *Saturn*, the intensity thus measured will be of the order θ^3, and will differ in fact from the average intensity of the whole ring by a term of the order $\frac{a^2}{\rho^2}\theta^4$, in which $\frac{a}{\rho}$ is the circular measure of the radius of the ring as seen from the Sun, *i.e.*, the circular measure of about $20''\cdot2$, and θ is the circular measure of about $102''\cdot3$. This small term may evidently be neglected. The surface of the rings is not truly plane, but an increase of brightness of any element of the surface will be balanced by a corresponding decrease on an opposite element, and so the average illumination of the whole surface will not be affected by the deviation from a plane.

In the annexed figure the circle represents the section of the hemisphere by the cone when the Sun has wholly risen. P_1Q_1, P_2Q_2, P_3Q_3, are the sections of this circle by the ring's plane when $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ of the Sun's diameter has risen.



1. If the radius of the hemisphere be unity, the radius of the circle will be $\sin\theta$ and its area $\pi\sin^2\theta$, projected at an inclination $\frac{\pi}{2}-\theta$ upon the ring's plane the intensity of illumination for the Sun just wholly risen is measured by $\pi\sin^3\theta$.

2. When the diameter P_2Q_2 is on the ring's plane, the projected area is the segment of a circle radius unity bounded by a chord equal to $2\sin\theta$, its value is

$$\theta-\sin\theta\cos\theta, \text{ or } \tfrac{2}{3}\theta^3 \text{ nearly.}$$

3. When P_1Q_1, which is equal to

$$2\sqrt{1-\cos^2\theta \, . \, \tan^2\frac{\theta}{2}}$$

is upon the ring-plane, *i.e.*, when the altitude of A

$$\text{is } \frac{\theta}{2},$$

and

$$N_2N_1=\cos\theta \, . \, \tan\frac{\theta}{2}$$

the projected area is the *difference* between a circular segment and an elliptic segment having the same chord P_1Q_1, its value is equal to

$$2\int_{\cos\theta \, . \, \sec\frac{\theta}{2}}^{1}\sqrt{1-x^2} \, . \, dx-2\sin\frac{\theta}{2}\int_{\cos\theta \, . \, \tan\frac{\theta}{2}}^{\sin\theta}\sqrt{\sin^2\theta-x^2} \, . \, dx.$$

Evaluated by the method of limits when θ is small, the value is

$$\left(\frac{3\sqrt{3}}{8}-\frac{\pi}{6}\right)\theta^2$$

4. When P_3Q_3 $(=P_1Q_1)$ is upon the ring-plane, *i.e.*, when the altitude of A is $\frac{\theta_3}{2}$, and $N_2N_3=N_2N_1$, the projected area is the *sum* of a circular segment and an elliptic segment (greater than half the ellipse) having the same chord P_3Q_3; its value may be derived from the last from the consideration that the *difference* between it and the last area is the ellipse formed by projecting the circle $\pi \sin^2\theta$ at an inclination of $\frac{\pi}{2}-\frac{\theta}{2}$, *i.e.*,

$$\pi \sin^2\theta \,.\, \sin\frac{\theta}{2}=\tfrac{1}{2}\pi\theta^3 \text{ nearly.}$$

Hence the area we require is

$$\left(\frac{\pi}{2}+\frac{3\sqrt{3}}{8}-\frac{\pi}{6}\right)\theta^2, \text{ or } \left(\frac{\pi}{3}+\frac{3\sqrt{3}}{8}\right)\theta^2.$$

The intensities of the illumination of the ring-plane by the Sun are in the four stages proportional to

$$\left(\frac{3\sqrt{3}}{8}-\frac{\pi}{6}\right),\ \tfrac{2}{3},\ \left(\frac{\pi}{3}+\frac{3\sqrt{3}}{8}\right),\ \pi.$$

that is to say, as

$$0{\cdot}12592 : 0{\cdot}66667 : 1{\cdot}69672 : 3{\cdot}14159,$$

or nearly, as

$$4 : 21 : 54 : 100.$$

Now the Sun's diameter at the mean distance from the Earth is $32'\ 3''{\cdot}64$ and on October $30^d\ 12^h$ G.M.T. (astro.), which I shall show to be the date given by Bessel's corrected formula for the hour when the Sun's centre was in the ring-plane, the logarithm of *Saturn's* heliocentric distance was 0·9744038. Hence, if x be the Sun's semi-diameter in seconds of arc, as seen from *Saturn* at this date,

$$L_{10} \sin x = L_{10} \sin 16'\ 1''{\cdot}82 - 0{\cdot}9744038,$$

whence

$$2x = 3'\ 24''{\cdot}66 = 204''{\cdot}66 = \text{Sun's diameter.}$$

But in the ten days between October 26 and November 5 the change of the Sun's altitude relative to the ring-plane was $0^\circ{\cdot}154$ according to Mr. Marth's ephemeris, or $55''{\cdot}44$ daily; and consequently the time required for the Sun's diameter to cross the ring-plane is

$$\frac{204''{\cdot}66}{55''{\cdot}44} \,.\, 24^h = 88^h{\cdot}19 \text{ nearly.}$$

Each of the four stages of sunrise follows its predecessor by 22 hours very nearly. The altitude of the Earth above the ring-plane differs very little from $2°5'$ during the 88 hours, its change is only to the extent of about 1 per cent. in 22 hours. Hence, the light received from the ring by an observer on the Earth will not differ appreciably from the proportions

$$4 : 21 : 54 : 100,$$

corresponding to the four stages of sunrise.

In addition to the observations reported by Mr. Barnard at Mount Hamilton, Mr. Comstock at Madison, Professor Oudemans at Utrecht, and by myself near Sittingbourne, all of which are published in the current volume of the *Monthly Notices*, I should wish to refer to the observation made by M. Léon Guiot at Soissons, France, October 30^d 18^h (*Astro. M.T.* of Paris), on which occasion he saw the ring represented by a fine line extending only one-eighth of the equatorial diameter of *Saturn* beyond the following limb (*L'Astronomie*, 1892 January). M. Guiot has informed me by letter that "on the following morning the ring was visible on both sides thin and long." This is a valuable confirmation of the momentary observation at Utrecht 40 minutes earlier. M. Guiot in his letter says that the instrument employed was a refractor of 10 centimetres aperture magnifying 150 times. It is probably the same as that which he used to observe the conjunction of ♃ and ♀ 1892 February 6, and which is stated more exactly to have an aperture of 95 m.m., or $3\frac{3}{4}$ inches (see *L'Astronomie*, 1892 March).

Recording the observations in order of G.M.T. (astro.) we have to nearest 5^m.

October 29^d 17^h 10^m, *Oudemans* ($10\frac{1}{4}$in. O.G.) Clear. *Saturn* decidedly without ring. Confirmed by myself with 6in. O.G. 45^m later.

October 30^d 1^h 5^m, *Barnard* (36in. O.G.) The rings were easily and distinctly visible as slender threads of light.

October 30^d 17^h 50^m, *Guiot* ($3\frac{3}{4}$in. O.G.) A fine bright line followed the East limb to a distance of only $\frac{1}{8}$ diameter of *Saturn*.

October 30^d 23^h 15^m, *Comstock* ($15\frac{3}{4}$in. O.G.) Rings plainly visible as continuous lines, extending on each side $\frac{3}{8}$ diameter of ball.

October 31^d 17^h 10^m, *Oudemans* ($10\frac{1}{4}$in. O.G.) Clouds. *Saturn* visible for a moment; at both sides the ring is visible as a thin bright line. Confirmed by Guiot with $3\frac{3}{4}$in. 40^m later.

November 1^d 17^h 30^m, *Freeman* (6in. O.G.) Bright blue ansæ seen on both sides of *Saturn* to a distance about $\frac{3}{8}$ of his diameter.

There can be no doubt that the great telescope of Mount Hamilton would exhibit the rings in the first stage of illumina-

tion rather more easily than the telescope I used would do so in the fourth stage, the *areas* of the object glasses being as 36 : 1, and the quantities of light from the rings as 1 : 25. It will be noticed that the interval of time between Mr. Barnard's observation and my own is $64^h\ 25^m$, whilst the interval between the first and fourth stages is 66^h. Again, the interval between Mr. Comstock's observation and my own is $42^h\ 15^m$, whilst the interval between the second and fourth stages is 44^h; in this case, too, the areas of the object glasses are as 7 : 1, and the light received as 1 : 5 nearly.

I am inclined to think that Mr. Comstock's observation was made at a point of time near to the instant when the centre of the Sun was in the plane of the rings; and that the Sun was almost if not quite fully risen above the plane of the rings when I saw the ansæ. Further observations from Observatories in Europe and Australia will, it may be hoped, yet be published, and contribute to determine the place of the node of the ring upon the ecliptic. I am decidedly of opinion that the appearances seen by Mr. Comstock and Mr. Townley, October 20, 25, 26, 27, are either views of the illuminated edges of the rings and of their principal divisions, when the Sun and Earth were on opposite sides of the rings, according to Bond's explanation in *Annals of Harvard Observatory*, vol. ii., Part I., pp. 118–120; or else, if G. A. Hirn's hypothesis be adopted, viz., that the rings are composed of separate satellites, *each with an atmosphere of its own*, revolving in circular orbits in planes inclined at diverse angles within small limits to the equator of *Saturn*, then the appearances seen at Washburn Observatory (previous to the real reappearance of the ring-plane caused by the beginning of actual sunrise) may have arisen from the light of the Sun being diffused through the interstices of this infinite number of satellites *by means of their atmospheres*, thereby giving a feeble illumination to that side of the ring-plane which was presented to the Earth. It is strange that no other observer but myself has stated the colour of the rings when first seen. This deficiency may yet be made good. To assist in the future discussion of the problem, I will add that the formulæ of Bessel, corrected by insertion of the truer values of δi, δn, and m, as found by Professor Oudemans (*Monthly Notices*, vol. xlix., p. 57), are

$$n = 167^\circ\ 18'\ 41''\cdot9 + 46''\cdot473\,(t - 1833)$$
$$\iota = 28^\circ\ 10'\ 32''\cdot1 + 0''\cdot351\,(t - 1833),$$

and for 1891 October $30^d\ 12^h = 1891\cdot8282$

$$n = 168^\circ\ 4'\ 15''\ 85, \quad \iota = 28^\circ\ 10'\ 11''\cdot45.$$

the change in one day or 0·0027 of a Julian year is unimportant. The *Nautical Almanac* gives for *Saturn*,

October $30^d\ 0^h$, Helioc Long. $172^\circ\ 3'\ 43''\cdot0$, Lat. $2^\circ\ 8'\ 34''\cdot9$.
October $31^d\ 0^h$, Helioc Long. $172^\circ\ 5'\ 46''\cdot2$, Lat. $2^\circ\ 8'\ 37''\cdot6$.

and upon the *hypothesis* of the node of the ring-plane on the ecliptic passing through the Sun's centre at either of these dates, the value of i being taken as on October $30^d\ 12^h$, we shall find for the longitude of the node corresponding to

October $30^d\ 0^h$......$168°\ 3'\ 18''\cdot1$.
October $31^d\ 0^h$......$168°\ 5'\ 16''\cdot2$.

from which it will appear that the value given by the formula of Bessel as corrected corresponds to October $30^d\ 11^h\cdot75$.

In conclusion, I may say that the most probable reasons for my not having seen any trace of the rings, October $30^d\ 18^h$, are (1) that I observed too short a time before sunrise, (2) that definition that morning was not nearly so good as on the two days previous, fewer belts being seen on the planet. The observations of Mr. Barnard and Mr. Comstock seem to have been made 81^m and 76^m before sunrise to them.

Murston Rectory, Sittingbourne:
1892 *May* 7.

Negatives of Jupiter, made with the Great Telescope of the Lick Observatory during 1891. By Edward S. Holden and W. W. Campbell.

We have the honour to present to the Royal Astronomical Society, in the name of the Lick Observatory, a series of negatives of *Jupiter*, made with the Great Telescope during the year 1891, in continuation of the work of 1890. A list of the negatives is given below. The following memoranda should accompany them. The negatives are all taken on 8 × 10 plates—Seed, No. 26. The enlargements are directly made, in the telescope, by means of an ordinary camera objective of 2 inches aperture and 14 inches focus, furnished us by Alvan Clark, Jun., for the purpose. This lens is used so as to give an enlargement of a little over eight diameters—that is, the negatives are affected by the wind blowing on the instrument (and by other accidental disturbances) as if they were taken in the principal focus of a telescope 400 feet long.

The enlargement employed is too great, and the enlarging lens itself is not entirely satisfactory. We hope to procure a new lens before the next opposition, which shall give better images and less magnifying.

All the exposures have been made by the two observers working together, and all the plates have been developed by Mr. Campbell. Each plate is intended to be marked with the date, the observers' initials, the setting of the enlarging lens in its tube (5·06), the setting of the negative plate on the focusing screw (1·0), the Pacific standard times of the beginning and

ending of each exposure, with notes on the weather. In these notes the words "Windy" and "Very windy" are far too common. The exposures varied between eight and twelve seconds, ten seconds being the usual one.

Several negatives were made each night, and the best have been selected and are preserved for reference at the Lick Observatory. All the other plates were called "duplicates," and as full a set of these as possible has been made up for presentation to the Royal Astronomical Society, irrespective of the excellence of the individual pictures. We desire to call attention to this fact, as our object has been to enable others to have all the data available for a study of the planet, and not at all to exhibit only the best results of our work. Even the poorest pictures have a statistical value. We have satisfied ourselves that when the atmospheric conditions are good (and especially when no wind is blowing) we can always produce results of uniform excellence. The number of pictures made in 1891 is smaller than it ordinarily will be, because the telescope was in use for making visual observations on the forms and the rotations of *Jupiter's* satellites on many of the nights which would otherwise have been devoted to photographic work.

Mount Hamilton:
1891 *December* 31.

List of Negatives of Jupiter.

Date 1891.		Name of Plate.	Number of Images on the Plate.	Approximate P.S.T. h m	Remarks.
Aug.	25	A^2	4	12 29	
	26	B^2	4	11 48	
Sept.	28	G^2	3	10 34	Very windy.
	28	F^2	3	10 43	Very windy.
	28	C^2	3	11 54	Very windy.
Oct.	11	H^2	3	9 0	
	11	G^1	3	10 8	
	11	I^2	3	11 7	Windy.
	12	B^2	3	8 57	Windy.
	25	A^2	3	8 56	Windy.
	25	H^1	3	9 40	Windy.
	25	I^1	3	11 17	Windy.

Photographic Search for a Planet beyond the Orbit of Neptune.
By Isaac Roberts, F.R.S.

The hypothesis that one or more planets exist beyond the orbit of *Neptune* has been long entertained by astronomers, and Professor Forbes, in a remarkable paper on "Comets and ultra-Neptunian Planets," which he read before the Royal Society of Edinburgh at the beginning of the year 1880, predicted with considerable confidence that one or two such planets exist, and in the paper referred to he gave very fully his reasons.

The prediction was based upon the recorded positions of the aphelia of a number of comets. He said,* "That there could be no longer a doubt but that two planets revolve in orbits external to that of *Neptune*, one about 100 times, the other about 300 times the distance of the Earth from the Sun."

In 1887, November, I wrote to Professor Forbes to ask him if he had further considered the hypothesis concerning the supposed planets, and that I was prepared to make a search for them by photographic methods. In his reply he stated that the present position of one of the hypothetical planets is $11^h\ 48^m$ R.A. and 3° N. Declination, and he believed that a range of 5° each way in R.A. and of 2° or 3° in Declination ought to find the planet if it is there. The motion of the planet he computed at one degree in 2·96 years.

I thereupon commenced the search, but soon found that the climate of Maghull was so unfavourable for celestial photographic work of this character that my task was nearly hopeless; but since the removal of my observatory to Crowborough I resumed the search under conditions sufficiently favourable to complete the work, which was conducted on the following plan:—

A chart was made of the region indicated by Professor Forbes between R.A. $11^h\ 24^m$ and R.A. $12^h\ 12^m$ with Declination 0° 0′ to 6° 0′ North. This region was covered by eighteen photographic plates, each of more than four square degrees in area, and allowed of sufficient overlap to show a number of the same stars on two or more contiguous plates. Two sets of photo-plates of the region were taken with an interval of not less than seven days between the exposures, which were of ninety minutes duration, and the dual photographs were subsequently compared three times over by superposition, in order to see if any star appeared on one plate which was not on the other, or to see if change in the position of any star had taken place in the interval between the dual exposures. In this way the whole of the plates covering the region were very carefully examined, and it now only remains for me to report that no planet of greater brightness than a star of the 15th magnitude

* *Memoir*, p. 3.

exists on the sky area herein indicated, nor is there on the plates any abnormal appearance to which it is necessary here to draw special attention. It is a region where the stars are not exceptionally numerous, and they are mostly faint.

Crowborough Hill, Sussex:
1892 *April* 12.

Photographs of the Region of the "Crab" Nebula, 1 *M Tauri.* By Isaac Roberts, F.R.S.

Two photographs of the region of the nebula 1 M *Tauri*, R.A. 5^h 29^m, Dec. $21°$ $57'$ N., are now presented, which have been enlarged from a negative taken with the 20-inch reflector on 1892, February 2, and exposure of three hours. One of the enlarged photographs is to the scale of one centimetre to four minutes of arc, and covers a sky area of ninety-two minutes of arc in Right Ascension by 112 minutes in Declination. The other photograph is enlarged to the scale of one centimetre to forty seconds of arc, and covers an area of nine minutes in diameter. The nebula measures 340 seconds of arc in extreme length by 260 seconds in breadth, and I counted sixteen stars involved in it.

The nebula is not symmetrical in form, and has a faint, undefined, boldly indented margin, with a large projecting limb on the south preceding side. It is oval in general outline, with the major axis in south following and north preceding direction, and on the north following side is a large deep embayment with little nebulosity in it, and there is also a smaller bay, but with nebulosity partly filling it. The negative shows dense massive cloudiness in parts of the nebula, with fainter areas between them, but they are too dense to print so as to be visible in detail on the enlargements.

I have not seen any drawing of this nebula that conveys even approximately an idea of its form as it is shown on the photograph, and there is no indication of the filamentous projections that are shown on some drawings, and which, if they had a real existence, would undoubtedly be shown.

The stars in the region of the nebula are very numerous, and when viewed on the negative the eye readily arranges them into festoons and wreaths of many patterns, but an enlargement, even to three and a half times, in great measure modifies this effect of perspective, which a larger magnifying power would dissipate.

On the Orbit of γ Coronæ Australis. By J. E. Gore.

Recent measures of the position-angle of this well-known southern binary star show clearly that the distance is now slowly but steadily increasing, and that the period will prove to be considerably longer than has been hitherto supposed. I find that the period given in my paper in the *Monthly Notices* for January 1886 is much too short, and the elements there given do not represent recent measures satisfactorily either in angle or distance. I have therefore re-computed the orbit by the Glasenapp-Kowalsky method, using all available measures, and now find the following provisional elements:—

Elements of γ Coronæ Australis.

$P = 154.41$ years	$\Omega = 77^\circ\ 14'$
$T = 1876.84$	$\lambda = 175\ 17$
$e = 0.4244$	$a = 2''.55$
$i = 35^\circ\ 35\frac{1}{2}'$	$\mu = -2^\circ.3314$

The following is a comparison between the measures and the positions computed from the above elements:—

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
		°	°	°	″	″	″
1834.47	Sir J. Herschel	37.1	38.0	−0.9	...	2.81	...
1835.55	"	36.8	36.4	+0.4	...	2.77	...
1836.43	"	34.5	35.1	−0.6	...	2.73	...
1837.43	"	32.7	33.6	−0.9	2.66	2.68	−0.02
1847.32	Jacob	14.1	15.0	−0.9	2.30	2.20	+0.10
1850.46	"	5.9	7.2	−1.3	2.29	2.05	+0.24
1851.54	"	4.5	4.4	+0.1	2.26	1.99	+0.27
1852.49	"	2.2	1.6	+0.6	1.9	1.95	−0.05
1853.52	"	359.0	358.5	+0.5	1.83	1.90	−0.07
1854.26	"	356.2	356.2	0.0	1.71	1.87	−0.16
1856.44	"	349.4	348.8	+0.6	1.67	1.78	−0.11
1857.44	"	347.4	345.2	+2.2	1.61	1.74	−0.13
1858.20	"	343.4	342.4	+1.0	1.53	1.71	−0.18
1859.72	Powell	338.1	336.4	+1.7	1½ est.	1.66	...
1861.69	"	328.8	328.1	+0.7	...	1.60	...
1862.27	"	325.5	325.6	−0.1	1½ est.	1.58	...
1863.84	"	318.1	318.3	−0.2	...	1.56	...
1870.19	"	286.9	287.4	−0.5	.	1.47	...
1875.65	Schiaparelli	257.4	259.6	−2.2	1.45	1.46	−0.01

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
1876·65	Howe	253°·1	254°·4	−1°·3	1″·67	1″·46	+0″·21
1877·43	Schiaparelli	248·4	250·4	−2·0	1·49	1·46	+0·03
1877·61	Howe	245·7	249·4	−3·7	1·37	1·46	−0·09
1877·69	O. Stone	249·4	249·0	+0·4	...	1·46	...
1878·49	„	242·4	244·8	−2·4	1·22	1·45	−0·23
1878·49	Howe	242·9	244·8	−1·9	1·47	1·45	+0·02
1879·69	Burnham	240·0	238·4	+1·6	0·87	1·44	−0·57
1880·46	Russell	233·1	234·3	−1·2	1·15	1·44	−0·29
1880·67	Hargrave	232·4	233·2	−0·8	1·32	1·44	−0·12
1881·72	O. Stone	225·5	227·6	−2·1	1·38	1·44	−0·06
1883·62	Wilson	217·7	217·4	+0·3	1·62	1·44	+0·18
1885·586	Pollock	200·3	201·5	−1·2	1·34	1·46	−0·12
1886·704	Russell	203·5	200·9	+2·6	1·52	1·46	+0·06
1886·705	Pollock	201·3	200·9	+0·4	1·68	1·46	+0·22
1887·689	„	196·6	195·8	+0·8	1·16	1·48	−0·32
1887·715	Tebbutt	196·7	195·7	+1·0	1·68	1·48	+0·20
1887·767	„	194·7	195·4	−0·7	...	1·48	...
1888·307	„	192·4	192·6	−0·2	1·59	1·49	+0·10
1888·637	„	187·9	190·9	−3·0	1·77	1·49	+0·28
1888·707	Leavenworth	188·0	190·6	−2·6	1·2	1·49	−0·29
1888·805	Tebbutt	191·9	190·1	+1·8	...	1·49	...
1889·41	Burnham	185·4	187·1	−1·7	1·79	1·50	+0·29
1889·843	Tebbutt	185·4	184·9	+0·5	...	1·51	...
1890·531	„	...	181·7	...	1·62	1·54	+0·08
1890·542	„	184·2	181·6	+2·6	...	1·54	...
1890·575	„	...	181·5	...	1·635	1·54	+0·095
1890·709	„	180·7	180·9	−0·2	1·54	1·54	0·0
1891·635	„	180·1	176·5	+3·6	1·57	1·57	0·0
1891·673	„	176·7	176·3	+0·4	...	1·57	...
1891·742	„	...	176·0	...	1·52	1·57	−0·05
1891·749	„	175·4	176·0	−0·6	...	1·57	...

According to the above orbit, the distance between the components will increase continuously during the next sixty years up to a maximum of about 3″·6.

Assuming that the mass of the system is equal to the mass of the Sun, the "hypothetical parallax" would be

$$p=\frac{a}{P^{\frac{2}{3}}}=0''\cdot088.$$

On the Orbit of γ Centauri. By J. E. Gore.

The measures of this southern binary star appear at first sight rather discordant. A closer examination, however, shows that the companion is revolving in a very elongated apparent ellipse, the real orbit being not only highly inclined to the line of sight but having a considerable eccentricity. I find that a complete revolution has been nearly performed since the star was measured by Sir John Herschel at the Cape in the years 1835 and 1836. Herschel's measures are somewhat discordant, ranging from 346·8 to 361·97; but measures in recent years show that if the position-angle was anything near 360° in 1835 and 1836, the distance between the components would have been nearly 2″, and they would have been easily divided with the 5-inch refractor used by Herschel. He estimated the distance, however, at only 0″·75, and says in the notes to his measures, "At least as close as γ *Virginis*; 273 barely elongates it . . . far too difficult for this telescope . . . excessively close and difficult." These remarks show that the distance could not have been anything like 2″ when Herschel measured it, and hence the position-angle must have been less than 360°, the motion being retrograde and not direct as Herschel supposed.

I have computed the orbit by the Glasenapp-Kowalsky method, and find the following provisional elements:—

Elements of γ Centauri.

P = 61·88 years	☊ = 177° 57′
T = 1840·84	λ = 46 49
e = 0·6316	a = 1″·50
i = 84° 6′	μ = −5°·817

P and T have been deduced from Herschel's measure at the epoch 1835·89, and Pollock's in 1889·323. The measures from 1856 to 1889 give a period of 62·68 years, and T = 1840·22, a close agreement.

The following is a comparison between the measures and the positions computed from the above elements:—

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
		°	°	°	″	″	″
1835·32	Sir J. Herschel	351·6	355·4	−3·4	...	0·98	...
1835·89	"	354·3	354·3	0·0	0·75	0·87	−0·1
1836·38	"	357·3	353·5	+3·8	...	0·78	...
1856·20	Jacob	20·6	22·3	−1·7	0·7 est.	0·48	+0·22
1857·973	"	13·71	16·37	−2·66	1·11	0·65	+0·46
1860·684	Powell	12·8	11·5	+1·3	...	0·89	...
1870·233	"	6·9	4·8	+2·1	1·5 est.	1·59	−0·09

Epoch.	Observer.	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
1871·386	Russell	3°8	4°3	−0°5	1″18	1″66	−0″48
1873·364	„	4·2	3·6	+0·6	2·29	1·76	+0·53
1874·260	„	1·6	3·3	−1·7	1·61	1·80	−0·19
1876·63	Ellery	8·5	2·6	(+5·9)	1·3	1·88	−0·58
1880·44	Russell	1·3	1·6	−0·3	1·39	1·97	−0·58
1882·22	Tebbutt	2·1	1·1	+1·0	...	...	...
1887·526	Pollock	358·5	359·6	−1·1	1·75	1·89	−0·14
1887·583	Tebbutt	359·1	359·6	−0·5	1·76	1·89	−0·13
1888·22	„	360·4	359·44	+0·96	1·56	1·86	−0·30
1888·325	„	...	359·41	...	1·70	1·86	−0·16
1888·335	„	358·9	359·41	−0·51	1·83	1·86	−0·03
1888·605	„	...	359·3	...	2·73	1·85	+0·88
1888·61	„	359·7	359·3	+0·4	...	1·85	...
1889·323	Pollock	359·1	359·1	0·0	1·87	1·81	+0·06
1890·361	Tebbutt	359·0	358·8	+0·2	1·84	1·76	+0·08

According to the above orbit the distance is now rapidly diminishing, and about the year 1901 will be reduced to about 0″·05, when it will probably pass beyond the reach of all existing telescopes.

Assuming the mass of the system to be equal to the mass of the Sun, the "hypothetical parallax" will be

$$\pi = aP^{-\frac{2}{3}} = 0''{\cdot}096$$

For a mass equal to twice the Sun's mass, the parallax would be 0″·076.

Note on the Orbit of α Centauri. By E. B. Powell, M.A., C.S.I.

In the *Monthly Notices*, No. 6, of April 1886, I submitted a paper on the orbit of *α Centuari*, in which the following elements were put forward:—

P = 87·438 years	$\gamma = 79^\circ\ 47'\ 8''$
T = 1875·447	☊ = 25 49 38
e = ·544326	λ = 48 59 17

and at the end of the paper I pointed out that in six or eight years, provided careful observations were taken, it would probably become apparent whether the period of that binary included only some seventy-six years or extended over eighty-six years or more. I cannot help thinking that now the evidence is

pretty decisive in support of the period extending over the longer time.

Taking the epochs from 1881 onwards, the following table gives a comparison, so far as the position-angle is concerned, of the results of observation (1) with those of the Downing-Elkin orbit, and (2) with those of the elements specified above.

Table of Comparison.

Observer.	Epoch 1800 +	θ_o	Downing-Elkin Orbit. θ_c	$\theta_o - \theta_c$	My Orbit of 1886. θ_c	$\theta_o - \theta_c$
Tebbutt	81·655	193°·15	194°·14	− °·99	193°·55	− °·40
Gill and Elkin	83·500	198·00	198·89	− ·89	198·14	− ·14
Tebbutt	84·533	199·80	200·53	− ·73	199·75	+ ·05
„	85·580	201·02	201·86	− ·84	201·03	− ·01
Pollock	86·517	202·17	202·66	− ·49	201·97	+ ·20
Tebbutt	86·603	201·80	202·89	− 1·09	202·05	− ·25
„	87·681	202·20	203·81	− 1·61	202·96	− ·76
„	88·467	203·20	204·47	− 1·27	203·55	− ·35
„	90·519	205·00	206·01	− 1·01	204·87	+ ·13
„	91·587	206·09	206·69	− ·60	205·46	+ ·63

It may be well to note that the annual angular motion between successive epochs, omitting 1886·517, is as follows, according to the two orbits:—

Downing-Elkin.	Orbit of 1886.		Downing-Elkin.	Orbit of 1886.	
2·57	2·49	Interval nearly two years.	·85	·84	
			·84	·75	
1·59	1·56		·75	·64	Interval slightly more than two years.
1·27	1·22				
1·01	1·00				
			·64	·55	

It will be seen that the Downing-Elkin orbit of 76·222 years now puts the comes a degree or so in advance of the observed position, while the orbit of 87·438 years generally agrees with the measured angles within what may perhaps be termed tolerably fair limits, having regard to the errors incidental to taking measures, the latest angle observed being in all probability somewhat too large. In making this remark I by no means imply that the elements given at the commencement of this note are absolutely correct; I believe they will all be found to need modification; but I consider the period is within (say) a year of the truth, and that the changes required in the others will be only small.

The semi-axis major, 18″·89, arrived at by me in 1886, is

undoubtedly too great. It is to be recollected that till lately, omitting from notice Sir John Herschel's observations, the distance measures, from which the value of the semi-axis has to be drawn, were generally much less than the quantity to be derived from them; consequently, a small error in a measure entailed a comparatively large one on the semi-axis. Now, however, for a good many years, the semi-axis will be less than the distance measures; therefore the former will no doubt be obtained with very considerable accuracy. So far as I can judge at present, the semi-axis major will not differ much from $18''\cdot4$.

It is to be hoped that observers occupying favourable localities will spare some portion of their time for the observation of *α Centauri*. Of late years, so far as I am aware, Mr. Tebbutt has been left almost alone to occupy the field; and all who are interested in the orbit of that binary must feel that they are much indebted to that astronomer for his assiduous attention to the star.

Streatham Hill:
1892 *April.*

Estimations of the magnitude of Nova Aurigæ. By J. Gerh. Lohse.

1892 February 1, 6^h 25^m G.M.T., 26 Aurigæ = Nova, 26 Aurigæ 1 Nova, Nova 3 *b*. The star *b* is south preceding of Nova Aurigæ.

February 3, 11^h 10^m G.M.T., Nova 2 χ Aurigæ.
February 4, 6^h 40^m G.M.T., Nova = χ Aurigæ.
February 5, 7^h 20^m G.M.T., Nova 3, perhaps 5, χ Aurigæ.
February 6, 7^h 10^m G.M.T., Nova 7 χ Aurigæ.

February 8, 8^h 0^m G.M.T., Nova Aurigæ not certainly identified owing to the close neighbourhood of the Moon. If the identification is right Nova is 8 χ Aurigæ.

February 9, 10^h 25^m G.M.T., Nova 3 χ Aurigæ, 10^h 40^m G.M.T., Nova 2 χ Aurigæ.

February 10, 7^h 40^m G.M.T., Nova = χ Aurigæ.

February 22, 10^h 48^m G.M.T., 26 Aurigæ 3 Nova, Nova $\doteq$ *b*, Nova is a little red.

March 23, 11^h 0^m G.M.T., Nova has become invisible.
March 24, 10^h 30^m G.M.T., Nova is invisible.

The observations were made with an opera-glass by Schröder.

The magnitudes of the comparison stars are according to the Bonn Durch-Musterung: χ Aurigæ = 4·8 magnitude, 26 Aurigæ = 6·0 magnitude, *b* = 6·2 magnitude.

The observations make *b* ·3 of a magnitude fainter than 26 Aurigæ, 6·3 has therefore been adopted for the magnitude of

b, while the values of the Durch-Musterung were taken for the two other stars.

The estimated magnitudes of Nova Aurigæ therefore are:—

Date. 1892.		Greenwich Mean Time. h m	Magnitude of Nova Aurigæ.
Feb.	1	6 25	6·0
	3	11 10	4·6
	4	6 40	4·8
	5	7 20	4·4
	6	7 10	4·1
	8	8 0	4·0 (?)
	9	10 32	4·55
	10	7 40	4·8
	22	10 48	6·3
Mar.	23	11 0	Invisible with the Opera-Glass.
	24	10 30	" " "

Comparison of Magnitudes of Nova Aurigæ and neighbouring stars, made with the Newall Telescope, Observatory, Cambridge. By H. F. Newall, M.A.

Observations on the brightness of the Nova have been made on many occasions since the discovery of the star was announced. Those of more recent date may be of interest, since all the comparison stars are mapped by Burnham (*Monthly Notices*, April, p. 433).

1892.		Nova.	Burnham's Comparison Stars.	
Mar.	24	Fainter than	F	10·4
	29	Brighter than	G	11·5
	31	Equal to	G	11·5
		Brighter than	H	11·8
		Fainter than	E	11·7
Apr.	1	Fainter than	E	11·7
	6	Fainter than	I	11·8
	8	Fainter than	J	12·7
	11	N. glimpsed whilst B 14·8 was not seen.		
	13	N. suspected once in many attempts to see it.		
	19	N. not seen or glimpsed, though B 14·8 and M were seen.		
	27	N. not seen; ground dark and comparison stars well seen.		

The companion to E was well seen, but C and D have not been seen. K I cannot speak of. All the other stars were

included in comparisons, but the companion to L was not even suspected.

I should have estimated magnitudes in all cases higher than Burnham's numbers, but my experience is not yet sufficient to warrant my committing myself to numerical estimates, and unfortunately our wedge photometer has only just been received, so that no measures have been made, though observations of faint stars chosen by the American Committee for stellar magnitude standards lead me to the view I have expressed about estimating magnitudes.

Observatory, Cambridge:
1892 *May* 13.

On a Diagram useful as a Guide in adjusting a Diffraction-Grating Spectroscope. By H. F. Newall, M.A.

The diagram which this note describes is intended to give at a glance the interpretation of the well-known relation

$$m\,\lambda = d\,(\sin\phi + \sin i)$$

which connects the angles of incidence i and of emergence ϕ of a beam of light of wavelength λ in a spectrum of order m produced by a plane diffraction grating, on which lines are ruled with an interval d between them.

The diagram has been constructed for a grating ruled with 14438 lines to the inch, which gives $d = 17592 \times 10^{-7}$ mm.

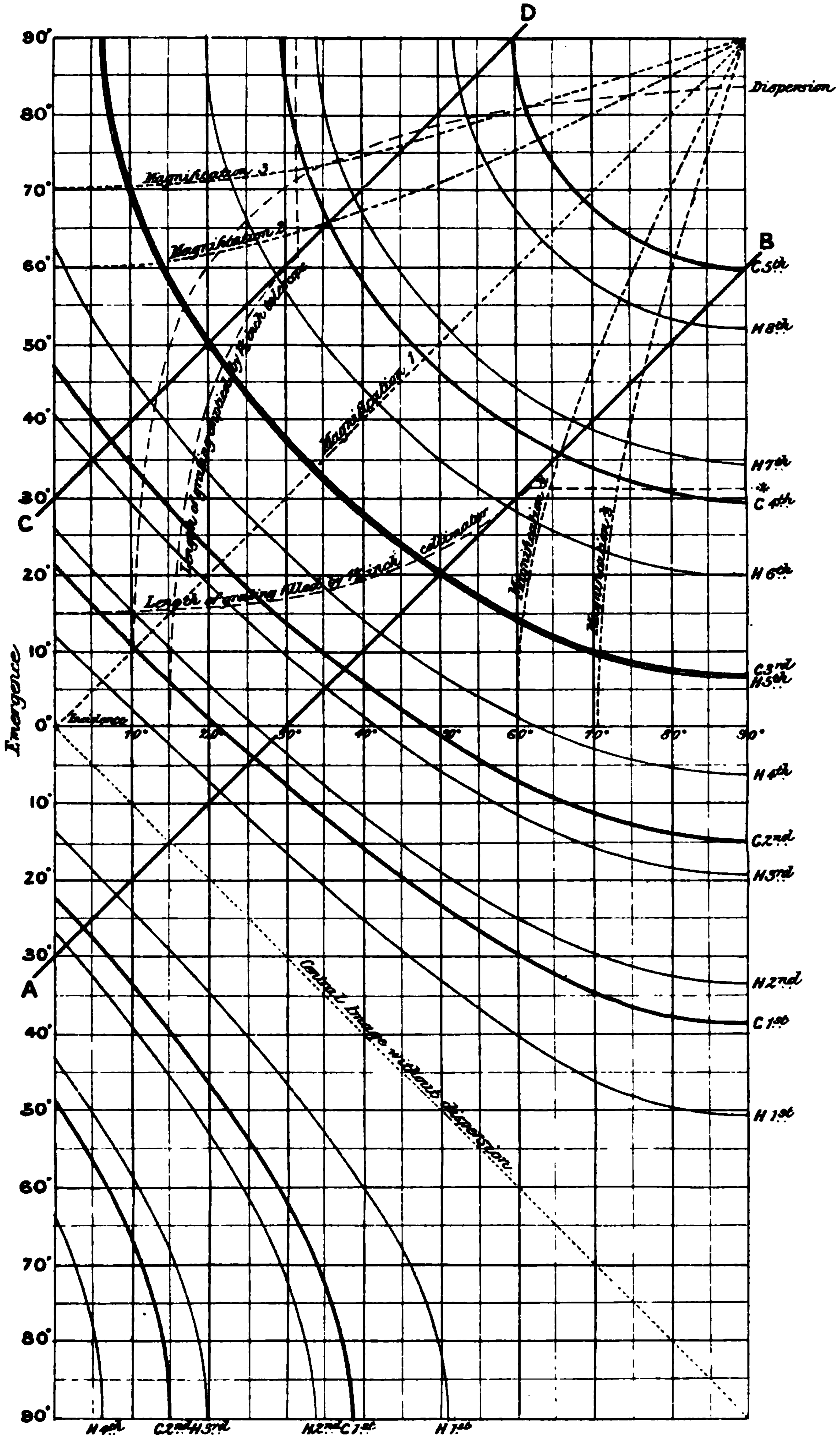
Two rectangular axes are taken; the length of incidence is represented by the length of a line measured off along the horizontal axis, which shall be called the axis of incidence; the angle of emergence of any diffracted beam is represented by a line measured off along the vertical axis, or axis of diffraction.

To explain the construction of the diagram, I describe the plotting of one curve. The following table shows the angle of emergence for the C line in the spectrum of the third order for varying angles of incidence. In above equation, $m=3$, $\lambda = 656{\cdot}18 \times 10^{-6}$ mm.

Incidence.	Emergence.	Incidence.	Emergence.
°	° ′	°	° ′
0	—	50	20 39
10	70 55	60	14 38
20	50 57	70	10 19
30	38 13	80	7 42
40	28 25	90	6 49

These values are plotted on the diagram, and the points so obtained are joined by a continuous curve.

Proceeding similarly for other orders of spectra, we cover



* If incidence is greater than 61°, some of incident beam is wasted

To accompany Note by H. F. Newall on a diagram useful as a guide in adjusting a diffraction grating spectroscope.

the diagram with curves for the C line. Again *mutatis mutandis* for the H line.

For application to the case of any particular spectroscope, we must consider what may be called the constraints of the spectroscope.

I. If the telescope and collimator are relatively fixed at an angle θ, whilst the grating is free to turn so as to make any incidence possible, then the emergence must satisfy the constraining condition $i \pm \phi = \theta$, and the sequence of phenomena in the telescope, as the grating is turned from a position in which incidence is perpendicular to a position in which incidence is grazing, is represented by the sequence of curves cut by a straight line $i \pm \phi = \theta$ (const.).

For instance, if telescope and collimator are inclined at an angle of 30°, we get the sequences along the lines AB and CD, which cut the axes at points corresponding to 30°, and are inclined at 45° to the axes.

II. If the grating and collimator be relatively fixed, so that the incidence is constant whilst the telescope is free to turn so as to catch a beam issuing with any angle of emergence, the sequence of phenomena in the telescope as it turns is shown by the sequence of curves cut by the straight line $i =$ const., which is a line parallel to the axis of diffraction.

III. If the grating and telescope are relatively fixed, so that the angle of emergence is constant, whilst the angle of incidence may be varied by turning the telescope and grating with respect to the collimated beam, then the sequence of phenomena in the telescope is shown on the line $\phi =$ const., a straight line parallel to the axis of incidences.

When the angles of incidence and emergence are such that the width of the beam is diminished by the action of the grating, then the action of the grating is magnifying, quite apart from the magnifications produced by the use of the telescope. I have plotted on the diagram lines of equal magnification for the arbitrary values 3, 2, 1, $\frac{1}{2}$, $\frac{1}{3}$ of the magnification.

The dispersion may be shown by another curve. I have plotted a curve on the diagram to show the relative dispersion in any spectrum, taking as unity the dispersion in that spectrum when it is observed when the telescope is perpendicular to the grating. In passing from a given order of spectrum to another, account must be taken of the change of order in considering the dispersion.

In much astronomical work the needless loss of light is to be avoided. It is of assistance, therefore, to have a curve showing what length of the grating is filled by a collimator of given aperture at varying incidences. I have plotted such a curve for a collimator of aperture 1·5 inches, and for a grating whose ruled

surface is $3\frac{1}{8}$ inches long. A second curve shows what length of grating will fill the telescope of aperture 1·5 inches at varying angles of emergence of the diffracted beam.

Consider a case in which it is desired to observe the C line in the spectrum of third order with a spectroscope in which the telescope and collimator are fixed at an angle of 30°. On the diagram it is seen that two positions of the grating are possible —one in which the action of the grating is magnifying, the other where it is the reverse. Which of these positions is best will depend on the object of the observation.

In this connection it may be remarked that the actual brightness of the spectra produced by a given grating probably depends on conditions which cannot be completely controlled, in the shape of the groove cut by the ruling diamond. The brightness of a given spectrum for given values of incidence and emergence is in general different according to which end of the ruled lines is uppermost (the lines being considered vertical). Hence, if particular values of incidence and emergence are desirable, the brightness may be in general increased or diminished by turning the grating "head for tail."

I am induced to publish the diagram, because I have found it of very great assistance in designing a spectroscope, and also in actual use of a grating spectroscope. So far as I am aware, no such diagram is accessible, though the simplicity of its construction would lead one to expect it has been long in use in laboratories.

Comet Swift, March 1892. By H. C. Russell, B.A., F.R.S.

We received the cablegram of the discovery of this comet on March 9, but owing to clouds could not see it until the morning of the 11th, when some micrometer measures were obtained, also a photograph, showing five equidistant rays, the outside ones enclosing an angle of 25°. There was not much difference in their length, the longest one measuring 35 minutes of arc. The exposure given was 1 hour 50 minutes, but owing to the frequent passage of thin cloud and the bright moonlight the picture of the rays is very faint. Cloudy weather again intervened, and we did not see the comet until the morning of the 22nd, when the air was much clearer, but there was a good deal of passing cloud; during an exposure of 2 hours 23 minutes clouds covered the comet for 28 minutes; the $11\frac{1}{2}$-inch equatoreal showed no tail except a slight hazy extension, and not a sign of any ray. The photograph shows no less than eight rays, two of which extend to the edge of the photograph and may have been even longer; the recorded length is, however, 1° 10′. On the side of these two long rays three new rays appear, and one of

these, shown in the photograph of March 11 as springing from the head, is now found at some distance from the head, and not visibly joined to it. The longest rays, as well as the three new ones, are on the south side of the tail, and these seem to have a definite connection with a jet from the nucleus, which extends forwards and then bends round to these rays.

On the morning of March 25 a break in the clouds occurred just before daybreak, and a photograph was taken with 15 minutes' exposure. This shows some of the rays close to the head, and the coma two-thirds of the diameter of it is shown on March 22. This affords a measure of the brightness of these parts, for with a similar sensitive plate, and 6 minutes' exposure, a star of the 11th magnitude would be photographed.

The rays in all the photographs are very faint, and their full extent only seen by looking through the negatives at a suitable light or at a cloudy sky. I send the negative of March 22, which shows the rays best. It will be observed that the plate has a *réseau* on it, and is, in fact, a star plate; and this afforded the opportunity of making an enlarged drawing of it, the details being very carefully drawn in each square by Mr. Sellors, so that the length, breadth, and positions of the rays are shown to scale. Their relative brilliance has been slightly increased in the drawing, so that they can be more easily seen in the photographic copies sent herewith than in the original. The weather and the moonlight have been against the photographs and the observations, and perhaps may to some extent account for the fact that these rays could not be seen with the 11½-inch. However, from their relative strength in the photograph, I am disposed to think that their actinic light is stronger than that of other parts—in fact, that we have here a picture of selected parts, selected by their actinic brightness, just as the sensitive plate brings to view in the brighter parts of some nebulæ details of structure which are invisible, under circumstances which seem to leave no doubt that the sensitive plate makes a selection amongst celestial colours as it does amongst terrestrial ones. I send (1) original negative of Swift's Comet, March 22; (2) negative of drawing of above, and (3) paper negative of the same. We obtained on the mornings of March 11, 22, 24 and 25 measures of the position of the comet with the 11½-inch equatoreal and filar micrometer. Those on the 24th were measured from a star not in the catalogues, which has not yet been observed.

Observatory, Sydney:
1892 *March* 27.

The photographs are placed in the Library.

Observations of Comet Swift, March 1892.

Filar Micrometer Observations, made with the 11½-inch refractor of the Sydney Observatory.

1892	Syd. M. T.	Δ R.A.	Δ N.P.D.	cp.	R.A. app.	log p. Δ	N.P.D. app.	log p. Δ	Red. to app. place.		✱	Observer.
	h m s	m s	′ ″		h m s		° ′ ″		s	″		
March 10	16 17 31	−0 18·97	+1 45·3	3	19 14 10·28	9·662*n*	118 43 34·2	0·359	−0·84	+5·6	1	R. P. Sellors
„ 21	16 50 20	−1 28·90	−5 2·4	11	20 4 33·15	9·589*n*	108 22 55·0	0·495	−0·70	+8·5	2	R. P. Sellors
„ 24	17 37 45	+2 34·42	+8 39·6	4	20 17 30·33	9·488*n*	105 16 7·0	0·503	−0·62	+9·2	3	H. C. Russell

Mean Places of Comparison Stars for 1892·0.

✱	R.A. 1892·0.	N.P.D. 1892·0.	Authority.
	h m s	° ′ ″	
1	19 14 30·09	118 41 43·3	Arg. Gen. Cat. 26481
2	20 6 2·75	108 27 48·9	Wash. Zones (1848), Zone 185, No. 77
3	20 14 56·53	105 7 18·3	β^2 *Capricorni*) Conn. des Temps, 1892

Observations of Swift's Comet (a 1892), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the East, or Sheepshanks, equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55. The observations are corrected for refraction, but not for parallax.

Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Appt. R.A. of ☄	Appt. N.P.D. of ☄	Comp. Star.
d h m s		s	s		′ ″	″			h m s	° ′ ″	
Apr. 22 14 7 0	A.C.	+ 30·57	+0·09	9·5786	+10 44·2	+0·1	0·8224	5	22 5 37·38	76 4 57·6	*a*
26 14 11 37	T.H.	+ 12·21	−0·03	9·5850	− 5 55·3	−0·3	0·8111	5	22 18 26·74	72 47 39·8	*b*
26 14 20 44	A.C.	+ 13·89	−0·03	9·5836	− 5 55·6	−0·1	0·8071	4	22 18 28·42	72 47 39·7	*b*
29 14 17 46	L.	+ 26·50	+0·04	9·5893	+ 9 39·9	+0·3	0·7995	4	22 27 48·29	70 29 29·3	*c*
29 14 21 57	C.D.	+ 26·65	+0·04	9·5884	+ 9 43·8	+0·2	0·7973	4	22 27 48·44	70 29 33·1	*c*
May 5 13 27 37	L.	+ 53·08	+0·10	9·6027	+16 24·0	+0·7	0·8134	3	22 45 40·06	66 14 44·6	*d*
5 13 38 7	„	+ 9·75	−0·04	9·6040	− 6 28·1	−0·1	0·8068	2	...	...	*e*
5 13 43 42	„	+ 18·13	+0·00	9·6044	+ 0 36·1	+0·0	0·8044	2	...	...	*f*
6 13 52 5	A.C.	+ 74·87	+0·05	9·6066	+13 32·4	+0·3	0·7953	3	22 48 38·83	65 34 17·8	*g*
6 14 1 37	„	− 8·92	−0·03	9·6058	− 9 17·0	−0·1	0·7835	5	22 48 38·73	65 34 1·2	*h*
6 14 7 33	„	+230·93	−0·06	9·6051	−24 22·5	−0·2	0·7836	2	22 48 37·78	65 33 57·1	*d*
7 13 58 17	B.	−393·70	−0·03	9·6080	− 8 28·3	0·0	0·7863	1	22 51 30·44	64 54 59·4	*k*
7 14 8 55	„	+361·15	−0·03	9·6069	−11 12·2	−0·2	0·7786	1	22 51 34·31	64 55 3·3	*l*
7 14 15 26	„	−620·00	−0·03	9·6053	−12 20·3	0·0	0·7738	2	22 51 30·45	64 54 45·2	*m*

Comparison Stars.

Star's Name.	Mean R.A., 1892·0. h m s	Mean N.P.D., 1892·0. ° ′ ″	Authority.
a. W.B. (1) XXII., 51	22 5 7·27	75 54 0·1	Glasgow Observations, 1870.
b. W.B. (1) XXII., 338	22 18 15·11	72 53 22·2	Weisse's Bessel.
c. 39 Pegasi	22 27 22·29	70 19 35·8	Greenwich Observations 1887 and 1890, combined with Ten-Year Catalogue, 1880.
d. μ Pegasi	22 44 37·39	65 58 6·7	Greenwich Five-Year Catalogue of Fundamental Stars, 1890.
e. B.D. + 23° 4621	22 45 32·4	66 20·8	Bonn Observations, vol. iv.
f. Anonymous	22 45 (24)	66 14	
g. B.D. + 24° 4678	22 47 24·42	65 20 32·0	Bonn Observations, vol. vi.
h. B.D. + 24° 4681	22 48 48·19	65 43 5·4	" " "
k. W.B. (2) XXII., 1292	22 58 4·72	65 3 15·1	Weisse's Bessel.
l. W.B. (2) XXII., 1026	22 45 33·66	65 6 2·6	" "
m. 56 Pegasi	23 1 51·05	65 6 53·0	Greenwich Observations, 1887, 1889, 1890, combined with Ten-Year Catalogue, 1880.

Notes.

April 26.—The comet was very faint and difficult to observe owing to mist. April 29.—Both observers noticed a short tail.

The places of the comet agree closely with Berberich's Ephemeris.

The initials L., A.C., T.H., B, C.D, are those of Mr. Lewis, Mr. Crommelin, Mr. Hudson, Mr. Bryant, and Mr. Davidson respectively.

Partial Eclipse of the Moon, 1892 May 11.

(*Communicated by the Astronomer Royal.*)

The following occultations of small stars were observed at Greenwich during the eclipse. Mr. Criswick (C.) used the 10-inch companion telescope to the photographic equatoreal and the clock Dent 2017. Mr. Lewis (L.) used the Sheepshanks equatoreal, aperture 6·7 inches, and the clock Earnshaw. Mr. Bryant (B.) used the altazimuth, aperture 4 inches, and the clock Graham I.

Star.	Observer.	Time Recorded.	Clock Fast.	Sidereal Time.	Mean Solar Time.
		h m s	s	h m s	h m s
B.D. – 19° 4091 Dis.	L.	13 37 13·2	5·03	13 37 8·0	10 16 31·1
" " "	B.	13 37 40	31·29	13 37 8·7	10 16 31·8
" – 19 4093 "	L.	13 40 45 (*a*)	5·03	13 40 40	10 20 2·5
" " "	C.	13 41 42·5	38·90	13 41 3·6	10 20 26·1
" – 18 4047 Re.	L.	13 52 30 (*b*)	5·06	13 52 25	10 31 46
" – 19 4095 Dis.	"	13 55 42·5	5·06	13 55 37·4	10 34 56·5
" " "	C.	13 56 15·0 (*c*)	38·91	13 55 36·1	10 34 55·2
" " "	B.	13 56 15 (*d*)	31·21	13 55 44	10 35 3
" – 19 4096 "	C.	14 3 54 (*e*)	38·92	14 3 15·1	10 42 33·9
" – 19 4087 Re.	"	14 19 0·0 (*f*)	38·92	14 18 21·1	10 57 37·5
" – 19 4097 Dis.	"	14 31 2·0	38·93	14 30 23·1	11 9 37·5
" " "	L.	14 29 50 (*g*)	5·13	14 29 44·9	11 8 59·4
" – 19 4099 "	"	14 32 56·5 (*h*)	5·13	14 32 51·4	11 12 5·4
" " "	"	14 33 4·3	5·13	14 32 59·2	11 12 13·2
" " "	C.	14 33 38·0	38·93	14 32 59·1	11 12 13·1
" " "	B.	14 33 25	31·08	14 32 53·9	11 12 7·9
" – 19 4091 Re.	L.	14 55 1·2	5·17	14 54 56·0	11 34 6·4

Notes.

(*a*) The time was noted as uncertain to the extent of 2ˢ. It does not appear to have been a true occultation.
(*b*) The time was noted as very rough.
(*c*) Considered a good observation.
(*d*) The time was noted as rough.
(*e*) Very faint; noted as doubtful.
(*f*) Time doubtful; a little way from limb when first seen.
(*g*) Glided along limb for some seconds.
(*h*) This is a double star; the times of disappearance are for the two components.

The following observations of the progress of the shadow were made by Mr. Lewis and Mr. Crommelin (A. C.) with the Sheepshanks and Mr. Bryant with the altazimuth:—

First Contact.

Phenomenon.		Observer.	Sidereal Time. h m s
Limb very smoky		A.C.	12 28 55
Contact of true shadow		"	12 31 55

Immersions of Craters.

Grimaldi	I.L.	A.C.	12 37 47
"	"	B.	12 36 44
"	II.L.	A.C.	12 40 52
Aristarchus	I.L.	"	12 38 45
"	II.L.	"	12 39 37
Copernicus	I.L.	"	12 53 15
"	II.L.	"	12 55 50
Plato	centre	"	12 54 40
"	II.L.	"	12 55 35
Tycho	I.L.	L.	13 29 22
"	"	B.	13 28 29
"	centre	L.	13 31 4
"	"	B.	13 32 4
"	II.L.	L.	13 32 50

Emersions of Craters.

Tycho	centre	A.C.	14 43 16
"	II.L.	"	14 45 4
Grimaldi	I.L.	"	14 48 15
Aristarchus	centre	"	15 10 15
"	II.L.	"	15 10 53
Copernicus	I.L.	"	15 13 38
"	centre	"	15 14 55
"	II.L.	"	15 16 14

Observations of Occultations of Stars by the Eclipsed Moon on 1892 May 11, at the Radcliffe Observatory, Oxford.

Communicated by E. J. Stone, Esq., F.R.S., Radcliffe Observer.

The following Disappearances were observed by Mr. Wickham, using the Barclay Equatoreal with power 90 and Solar Chronometer Dent 44675.

Name.	Mag.	Time by Chronometer.	Observed G.M.T.	Remarks.
		h m s	h m s	
B.D. -18° 4047	9·0	9 48 13·2	9 47 56·6	Good; instantaneous.
-19 4091	8·3	10 15 24·2	10 15 7·5	Very good.
-19 4093	9·2	10 19 4·3	10 18 47·6	Rather slow.
-19 4095	8·9	10 33 22·2	10 33 5·4	Good.

The disappearance of B.D. -19° 4087 was not seen, being too near the illuminated limb.

The reappearance of B.D. -18° 4047, mag. 9·0, was looked for, both before predicted time and for quite five minutes after. The observer then suspecting some error, turned rapidly to the chronometer to check his count; looking back immediately into the telescope he saw the star had just reappeared and was still in contact with the limb. The G.M.T. of reappearance $10^h\ 30^m\ 47^s$ is, therefore, approximate only.

At $10^h\ 43^m$ the sky became overcast, and continued so during the remaining time of the eclipse.

Radcliffe Observatory, Oxford:
1892 *May* 13.

Ephemeris of the Satellites of Mars, 1892. By A. Marth.

Greenwich Noon.	P	a_1	b_1	u_1-U	a_2	b_2	u_2-U	U	B
	Phobos.				*Deimos.*				
1892.	°	"	"	°	"	"	°	°	°
June 10	1·46	22·43	−6·13	255·92	56·12	−15·34	244·54	267·67	−15·86
12	1·10	22·91	6·28	353·12	57·33	15·71	94·31	268·24	15·90
14	0·77	23·40	6·42	90·36	58·57	16·07	304·12	268·77	15·93
16	0·46	23·91	6·56	187·63	59·83	16·43	153·97	269·26	15·94
18	0·18	24·42	6·70	284·93	61·11	16·77	3·86	269·72	15·93
20	359·92	24·94	−6·84	22·28	62·41	−17·11	213·79	270·14	−15·91
22	359·68	25·47	6·97	119·67	63·73	17·43	63·76	270·51	15·87
24	359·48	26·00	7·09	217·10	65·06	17·74	273·77	270·83	15·82
26	359·30	26·53	7·20	314·57	66·40	18·03	123·83	271·11	15·75
28	359·16	27·07	7·31	52·09	67·75	18·30	333·94	271·34	15·67
30	359·04	27·61	−7·41	149·66	69·10	−18·55	184·10	271·53	−15·57
July 2	358·96	28·15	7·50	247·27	70·45	18·78	34·30	271·66	15·46
4	358·90	28·69	7·59	344·93	71·79	18·98	244·55	271·75	15·33
6	358·88	29·22	7·66	82·64	73·12	19·16	94·86	271·78	15·19
8	358·89	29·74	7·72	180·39	74·42	19·31	305·21	271·77	15·04
10	358·93	30·25	−7·77	278·19	75·69	−19·43	155·61	271·70	−14·88
12	359·00	30·74	7·80	16·04	76·93	19·52	6·06	271·58	14·70
14	359·10	31·22	7·82	113·94	78·13	19·58	216·56	271·42	14·52
16	399·24	31·67	7·83	211·88	79·27	19·61	67·11	271·21	14·32
18	359·40	32·10	7·83	309·86	80·35	19·60	277·70	270·95	14·12
20	359·59	32·51	−7·81	47·89	81·35	−19·56	128·34	270·64	−13·91
22	359·81	32·88	7·78	145·96	82·27	19·48	339·02	270·29	13·70
24	0·06	33·21	7·74	244·06	83·10	19·37	189·73	269·91	13·48
26	0·33	33·50	7·68	342·19	83·83	19·23	40·48	269·49	13·26
28	0·61	33·75	7·62	80·34	84·45	19·06	251·26	269·05	13·04
30	0·91	33·95	−7·54	178·51	84·95	−18·87	102·06	268·58	−12·83
Aug. 1	1·22	34·10	7·45	276·90	85·33	18·65	312·87	268·09	12·62
3	1·54	34·20	7·36	14·89	85·59	18·41	163·70	267·59	12·42
5	1·87	34·26	7·26	113·09	85·72	18·16	14·53	267·09	12·23
7	2·20	34·26	7·16	211·29	85·73	17·90	225·36	266·58	12·05
9	2·52	34·21	−7·05	309·48	85·61	−17·63	76·18	266·08	−11·89
11	2·84	34·11	6·94	47·65	85·37	17·36	287·00	265·59	11·74
13	3·15	33·97	6·83	145·81	85·00	17·10	137·80	265·11	11·61
15	3·45	33·78	6·73	243·94	84·52	16·84	348·58	264·65	11·49

Greenwich Noon.	P	*Phobos.* a_1	b_1	u_1-U	*Deimos.* a_2	b_2	u_2-U	U	B
1892.	°	"	"	°	"	"	°	°	°
Aug. 17	3·73	33·54	6·63	342·04	83·93	16·58	199·33	264·22	11·40
19	3·99	33·26	−6·53	80·11	83·23	−16·34	50·05	263·81	−11·32
21	4·23	32·94	6·44	178·15	82·44	16·11	260·74	263·44	11·27
23	4·44	32·59	6·36	276·14	81·56	15·90	111·39	263·11	11·24
25	4·63	32·20	6·28	14·09	80·59	15·71	321·99	262·82	11·24
27	4·79	31·79	6·21	111·99	79·56	15·54	172·55	262·58	11·26
29	4·91	31·36	−6·15	209·84	78·47	−15·38	23·07	262·38	−11·30
31	5·00	30·90	6·10	307·64	77·33	15·24	233·53	262·23	11·37
Sept. 2	5·06	30·43	6·05	45·38	76·15	15·13	83·94	262·13	11·46
4	5·09	29·94	6·01	143·08	74·93	15·04	294·31	262·08	11·58
6	5·08	29·45	5·98	240·72	73·69	14·96	144·62	262·08	11·71
8	5·04	28·94	−5·96	338·31	72·43	−14·90	354·88	262·14	−11·87
10	4·97	28·43	5·94	75·84	71·16	14·85	205·09	262·24	12·05
12	4·87	27·92	5·92	173·33	69·88	14·82	55·25	262·39	12·25
14	4·74	27·41	5·91	270·76	68·59	14·80	265·36	262·58	12·46
16	4·58	26·90	5·91	8·15	67·31	14·79	115·42	262·83	12·69
18	4·38	26·39	−5·91	105·48	66·03	−14·79	325·44	263·13	−12·94
20	4·15	25·88	5·91	202·76	64·76	14·80	175·41	263·47	13·21
22	3·90	25·38	5·92	300·00	63·50	14·81	25·33	263·86	13·49
24	3·62	24·88	5·93	37·19	62·26	14·83	235·20	264·29	13·78
26	3·31	24·39	5·94	134·34	61·04	14·86	85·03	264·77	14·09
28	2·98	23·91	−5·95	231·44	59·83	−14·89	294·82	265·29	−14·41
30	2·62	23·44	5·96	328·49	58·65	14·92	144·56	265·85	14·73
Oct. 2	2·24	22·97	5·97	65·51	57·49	14·95	354·27	266·45	15·07
4	1·83	22·52	5·98	162·48	56·35	14·98	203·94	267·09	15·41
6	1·40	22·07	6·00	259·42	55·24	15·01	53·57	267·76	15·76
8	0·96	21·64	−6·01	356·32	54·15	−15·04	263·16	268·47	−16·12

The differences between successive values of u_1-U range between 2256°·90 and 2258°·20, and of u_2-U between 569°·59 and 570°·83.

The values of P, a, b, $u-U$ are to be interpolated directly for the times for which the positions of the satellites are required, and the position-angles p and distances s are then found by means of the formulæ:—

$$s \sin(p-P) = a \sin(u-U)$$
$$s \cos(p-P) = b \cos(u-U).$$

Approximate Greenwich times, at which the satellites will be at their greatest elongations (*e* in position P + 90° and *w* in position P − 90°), the designation, in the case of Phobos, belonging to both given times, so that an elongation on the opposite side occurs at mid-time between them:—

1892.	Phobos. h		h	Deimos. h	1892.	Phobos. h		h	Deimos. h
June 10	15·6	*w*	23·3	17·3 *e*	July 12	13·1	*w*	20·7	22·2 *w*
11	14·6	*w*	22·2	23·6 *e*	13	15·8	*e*	23·5	13·3 *e*
12	13·5	*w*	21·2	14·8 *w*	14	14·8	*e*	22·4	19·6 *e*
13	12·5	*w*	20·2	21·1 *w*	15	13·8	*e*	21·4	10·8 *w*
14	15·3	*e*	23·0	12·3 *e*	16	12·7	*e*	20·4	17·1 *w*
15	14·3	*e*	21·9	18·6 *e*	17	15·5	*w*	23·2	23·3 *w*
16	13·2	*e*	20·9	24·9 *e*	18	14·5	*w*	22·1	14·5 *e*
17	16·0	*w*	23·7	16·1 *w*	19	13·4	*w*	21·1	20·8 *e*
18	15·0	*w*	22·6	22·4 *w*	20	16·2	*e*	23·9	11·9 *w*
19	14·0	*w*	21·6	13·6 *e*	21	15·2	*e*	22·8	18·2 *w*
20	12·9	*w*	20·6	19·9 *e*	22	14·1	*e*	21·8	24·5 *w*
21	15·7	*e*	23·4	11·0 *w*	23	13·1	*e*	20·7	15·6 *e*
22	14·7	*e*	22·3	17·4 *w*	24	12·0	*e*	19·7	21·9 *e*
23	13·6	*e*	21·3	23·7 *w*	25	14·8	*w*	22·5	13·0 *w*
24	16·4	*w*	24·1	14·8 *e*	26	13·8	*w*	21·4	19·3 *w*
25	15·4	*w*	23·0	21·1 *w*	27	12·7	*w*	20·4	10·4 *e*
26	14·4	*w*	22·0	12·3 *w*	28	15·5	*e*	23·2	16·7 *e*
27	13·3	*w*	21·0	18·6 *w*	29	14·5	*e*	22·1	23·0 *e*
28	16·1	*e*	23·8	24·9 *w*	30	13·4	*e*	21·1	14·1 *w*
29	15·1	*e*	22·7	16·1 *e*	31	12·4	*e*	20·0	20·4 *w*
30	14·0	*e*	21·7	22·4 *e*	Aug. 1	15·2	*w*	22·8	11·5 *e*
July 1	13·0	*e*	20·7	13·5 *w*	2	14·1	*w*	21·8	17·8 *e*
2	15·8	*w*	23·4	19·8 *w*	3	13·1	*w*	20·7	24·1 *e*
3	14·7	*w*	22·4	11·0 *e*	4	12·0	*w*	19·7	15·2 *w*
4	13·7	*w*	21·4	17·3 *e*	5	11·0	*w*	18·6	21·5 *w*
5	12·7	*w*	20·3	23·6 *e*	6	13·8	*e*	21·4	12·6 *e*
6	15·5	*e*	23·1	14·7 *w*	7	12·7	*e*	20·4	18·9 *e*
7	14·4	*e*	22·1	21·0 *w*	8	11·7	*e*	19·3	10·0 *w*
8	13·4	*e*	21·0	12·2 *e*	9	10·6	*e*	18·3	16·3 *w*
9	12·3	*e*	20·0	18·5 *e*	10	13·4	*w*	21·1	22·6 *w*
10	15·1	*w*	22·8	24·8 *e*	11	12·4	*w*	20·0	13·7 *e*
11	14·1	*w*	21·7	15·9 *w*	12	11·3	*w*	19·0	20·0 *e*

	Phobos.			Deimos.		Phobos.			Deimos.
1892.	h		h	h	1892.	h		h	h
Aug. 13	10·3	w	17·9	11·1 w	Sept. 11	10·7	w	18·4	11·8 w
14	13·1	e	20·7	17·4 w	12	9·7	w	17·4	18·1 w
15	12·0	e	19·7	8·5 e	13	8·7	w	16·3	9·2 e
16	11·0	e	18·6	14·8 e	14	7·6	w	15·3	15·5 e
17	9·9	e	17·6	21·1 e	15	10·4	e	18·1	6·7 w
18	12·7	w	20·4	12·2 w	16	9·4	e	17·0	13·0 w
19	11·7	w	19·3	18·5 w	17	8·3	e	16·0	19·3 w
20	10·6	w	18·3	9·6 e	18	7·3	e	15·0	10·5 e
21	9·6	w	17·3	15·9 e	19	10·1	w	17·8	16·8 e
22	12·4	e	20·0	22·2 e	20	9·1	w	16·7	8·0 w
23	11·3	e	19·0	13·3 w	21	8·0	w	15·7	14·3 w
24	10·3	e	17·9	19·6 w	22	7·0	w	14·7	20·6 w
25	9·3	e	16·9	10·8 e	23	9·8	e	17·5	11·8 e
26	12·0	w	19·8	17·1 e	24	8·8	e	16·4	18·1 e
27	11·0	w	18·7	8·2 w	25	7·7	e	15·4	9·2 w
28	10·0	w	17·6	14·5 w	26	10·5	w	18·2	15·6 w
29	12·8	e	20·4	20·8 w	27	9·5	w	17·2	6·7 e
30	11·7	e	19·4	11·9 e	28	8·5	w	16·1	13·1 e
31	10·7	e	18·3	18·2 e	29	7·4	w	15·1	19·4 e
Sept. 1	9·6	e	17·3	9·4 w	30	6·4	w	14·1	10·6 w
2	8·6	e	16·2	15·6 w	Oct. 1	9·2	e	16·9	16·9 w
3	11·4	w	19·0	21·9 w	2	8·2	e	15·8	8·1 e
4	10·3	w	18·0	13·1 e	3	7·1	e	14·8	14·4 e
5	9·3	w	17·0	19·4 e	4	6·1	e	13·8	5·6 w
6	8·3	w	15·9	10·5 w	5	8·9	w	16·6	11·9 w
7	11·1	e	18·7	16·8 w	6	7·9	w	15·5	18·2 w
8	10·0	e	17·7	8·0 e	7	6·8	w	14·5	9·4 e
9	9·0	e	16·6	14·3 e	8	9·6	e	17·3	15·7 e
10	7·9	e	15·6	20·6 e	9	8·6	e	16·3	6·9 w

Ephemeris for Physical Observations of

Greenwich Noon.		Angle of Position of ♃'s Axis. P	L−O.	Diff.	B	Annual Parallax. A−L.	Apparent Diameter. Equat.	Phase.	Polar.
1892.		°	°		°	°	"	"	"
July	30	337·119	249·189	88	+3·006	−11·533	42·07	0·43	39·46
Aug.	1	·136	·277	75	3·017	11·437	42·44	·42	39·72
	3	·150	·352	62	3·028	11·328	42·71	·42	39·97
	5	·163	·414	49	3·038	11·207	42·99	·41	40·23
	7	·173	·463	36	3·048	11·072	43·26	·40	40·48
	9	337·180	249·499	23	+3·058	−10·925	43·53	0·39	40·74
	11	·185	·522	10	3·067	10·765	43·81	·39	41·00
	13	·187	·532	3	3·076	10·591	44·08	·38	41·25
	15	·187	·529	17	3·085	10·404	44·36	·37	41·51
	17	·185	·512	30	3·093	10·203	44·63	·35	41·76
	19	337·179	249·482	43	+3·101	− 9·989	44·89	0·34	42·01
	21	·171	·439	57	3·108	9·762	45·16	·33	42·26
	23	·161	·382	70	3·115	9·522	45·52	·31	42·51
	25	·148	·312	83	3·121	9·268	45·68	·30	42·75
	27	·133	·229	96	3·127	9·001	45·94	·28	42·99
	29	337·115	249·133	109	+3·132	− 8·722	46·19	0·27	43·22
	31	·095	249·024	121	3·137	8·430	46·43	·25	43·45
Sept.	2	·073	248·903	134	3·141	8·125	46·67	·23	43·68
	4	·049	248·769	145	3·145	7·808	46·90	·22	43·89
	6	337·023	248·624	157	3·148	7·479	47·12	·20	44·10
	8	336·995	248·467	168	+3·151	− 7·139	47·34	0·18	44·30
	10	·964	248·299	179	3·153	6·787	47·55	·17	44·50
	12	·932	248·120	190	3·154	6·424	47·75	·15	44·68
	14	·898	247·930	200	3·155	6·051	47·93	·13	44·86
	16	·863	247·730	209	3·155	5·668	48·11	·12	45·03
	18	336·826	247·521	218	+3·154	− 5·275	48·28	0·10	45·18
	20	·787	247·303	226	3·153	4·873	48·44	·09	45·33
	22	·748	249·077	234	3·151	4·463	48·58	·07	45·46
	24	·708	246·843	242	3·148	4·045	48·71	·06	45·58
	26	·667	246·601	248	3·145	3·620	48·83	·05	45·70
	28	336·625	246·353	253	+3·141	− 3·189	48·93	0·04	45·80
	30	·583	246·100	258	3·137	2·752	49·02	·03	45·88
Oct.	2	·540	245·842	262	3·132	2·310	49·10	·02	45·95
	4	·497	245·580	265	3·126	1·865	49·16	·01	46·01
	6	·454	245·315	268	3·120	1·416	49·21	·01	46·05

Jupiter, 1892 (*continued*). By A. Marth.

Greenwich Noon.	Longitude of ♃'s Central Meridian (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A−O.	B
1892.	°	°	°	m	°	°
July 30	229·40	48·90	+0·58	38·403	237·6587	+2·5948
Aug. 1	185·26	349·50	·57	38·156	237·8423	2·6001
3	141·13	290·12	·56	37·912	238·0259	2·6053
5	97·02	230·74	·55	37·670	238·2095	2·6105
7	52·92	171·37	·53	37·431	238·3931	2·6156
9	8·82	112·02	+0·52	37·195	238·5767	+2·6207
11	324·74	52·68	·50	36·962	238·7603	2·6258
13	280·67	353·35	·49	36·732	238·9439	2·6309
15	236·61	294·03	·47	36·506	239·1275	2·6360
17	192·57	234·72	·45	36·285	239·3111	2·6410
19	148·53	175·42	+0·43	36·068	239·4948	+2·6460
21	104·50	116·13	·41	35·855	239·6784	2·6509
23	60·49	56·85	·39	35·648	239·8620	2·6559
25	16·48	357·59	·37	35·446	240·0456	2·6608
27	332·48	298·33	·35	35·249	240·2292	2·6657
29	288·49	239·08	+0·33	35·059	240·4128	+2·6705
31	244·51	179·84	·31	34·875	240·5964	2·6753
Sept. 2	200·54	120·61	·29	34·697	240·7800	2·6801
4	156·58	61·39	·27	34·526	240·9636	2·6849
6	112·63	2·17	·24	34·362	241·1472	2·6897
8	68·68	302·96	+0·22	34·205	241·3308	+2·6944
10	24·74	243·76	·20	34·056	241·5144	2·6991
12	340·81	184·56	·18	33·914	241·6980	2·7038
14	296·88	125·37	·16	33·781	241·8816	2·7084
16	252·95	66·19	·14	33·656	242·0652	2·7130
18	209·03	7·01	+0·12	33·539	242·2487	+2·7176
20	165·11	307·83	·10	33·431	242·4323	2·7211
22	121·20	248·66	·09	33·332	242·6159	2·7256
24	77·29	189·49	·07	33·243	242·7994	2·7301
26	33·38	130·32	·06	33·163	242·9830	2·7346
28	349·47	71·15	+0·04	33·092	243·1666	+2·7390
30	305·56	11·98	·03	33·031	243·3501	2·7434
Oct. 2	261·65	312·81	·02	32·980	243·5337	2·7478
4	217·74	253·63	·02	32·938	243·7172	2·7522
6	173·82	194·46	·01	32·908	243·9007	2·7565

Greenwich Noon.		Angle of Position of ♃'s Axis. P	L−O.	Diff.	B	Annual Parallax. A−L.	Apparent Diameter. Equat.	Phase.	Polar.
1892.		°	°		°	°	″	″	″
Oct.	8	336·411	245·047	270	+3·113	− 0·965	49·24	·00	46·08
	10	·368	244·777	270	3·105	0·512	49·26	...	46·10
	12	·326	244·507	270	3·097	− 0·058	49·26	...	46·10
	14	·284	244·237	270	3·088	+ 0·396	49·24	...	46·08
	16	·243	243·967	268	3·079	0·850	49·21	·00	46·06
	18	336·202	243·699	266	+3·069	+ 1·301	49·17	0·01	46·02
	20	·162	243·433	263	3·059	1·750	49·11	·01	45·96
	22	·123	243·170	258	3·048	2·196	49·04	·02	45·89
	24	·085	242·912	253	3·037	2·638	48·95	·03	45·81
	26	·048	242·659	247	3·026	3·075	48·84	·04	45·71
	28	336·013	242·412	241	+3·014	+ 3·506	48·73	0·05	45·60
	30	335·979	242·171	234	3·002	3·930	48·59	·06	45·48
Nov.	1	·946	241·937	225	2·989	4·347	48·45	·07	45·34
	3	·914	241·712	217	2·977	4·756	48·29	·08	45·19
	5	·884	241·495	208	2·964	5·156	48·12	·10	45·04
	7	335·856	241·287	199	+2·951	+ 5·547	47·94	0·11	44·87
	9	·829	241·088	188	2·938	5·929	47·75	·13	44·69
	11	·804	240·900	177	2·925	6·301	47·55	·14	44·50
	13	·781	240·723	166	2·912	6·662	47·34	·16	44·30
	15	·759	240·557	155	2·899	7·011	47·12	·18	44·09
	17	335·739	240·402	142	+2·886	+ 7·349	46·89	0·19	43·88
	19	·720	240·260	130	2·873	7·675	46·65	·21	43·66
	21	·703	240·130	117	2·860	7·988	46·40	·23	43·43
	23	·688	240·013	104	2·847	8·288	46·15	·24	43·19
	25	·675	239·909	90	2·835	8·576	45·89	·26	42·95
	27	335·663	239·819	77	+2·822	+ 8·850	45·63	0·27	42·70
	29	·653	239·742	63	2·810	9·110	45·36	·29	42·45
Dec.	1	·645	239·679	50	2·798	9·356	45·09	·30	42·20
	3	·639	239·629	35	2·787	9·589	44·82	·31	41·94
	5	·635	239·594	22	2·776	9·808	44·54	·33	41·68
	7	335·632	239·572	8	+2·765	+10·013	44·26	0·34	41·42
	9	·631	239·564	6	2·754	10·204	43·97	·35	41·15
	11	·631	239·570	20	2·744	10·381	43·69	·36	40·88
	13	·633	239·590	34	2·734	10·544	43·40	·37	40·62
	15	·636	239·624	48	2·725	10·693	43·12	·37	40·35
	17	335·642	239·672	62	+2·716	+10·829	42·83	0·38	40·08
	19	·649	239·734	75	2·707	10·951	42·55	·39	39·82

Greenwich Noon.	Longitude of ♃'s Central Meridian (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A−O.	B
1892.	°	°	°	m	°	°
Oct. 8	129·90	135·28	·00	32·886	244·0843	+2·7618
10	85·98	76·10	...	32·875	244·2678	2·7661
12	42·05	16·91	...	32·874	244·4513	2·7703
14	358·11	317·71	...	32·883	244·6348	2·7745
16	314·17	258·51	·00	32·902	244·8184	2·7787
18	270·22	199·30	−0·01	32·932	245·0019	+2·7829
20	226·27	140·08	·01	32·972	245·1854	2·7870
22	182·30	80·85	·02	33·022	245·3689	2·7911
24	138·32	21·61	·03	33·082	245·5524	2·7952
26	94·33	322·36	·04	33·152	245·7359	2·7992
28	50·33	263·10	−0·05	33·232	245·9193	+2·8032
30	6·32	203·83	·07	33·322	246·1028	2·8072
Nov. 1	322·29	144·54	·08	33·421	246·2863	2·8111
3	278·25	85·24	·10	33·530	246·4697	2·8150
5	234·19	25·93	·12	33·647	246·6532	2·8189
7	190·12	326·60	−0·13	33·774	246·8366	+2·8228
9	146·04	267·26	·15	33·910	247·0200	2·8266
11	101·94	207·90	·17	34·054	247·2034	2·8304
13	57·82	148·53	·19	34·206	247·3868	2·8342
15	13·69	89·14	·21	34·367	247·5702	2·8380
17	329·54	29·73	−0·24	34·535	247·7536	+2·8417
19	285·38	330·30	·26	34·711	247·9370	2·8454
21	241·20	270·86	·28	34·895	248·1204	2·8490
23	197·00	211·40	·30	35·085	248·3037	2·8526
25	152·78	151·93	·32	35·282	248·4871	2·8562
27	108·55	92·44	−0·34	35·486	248·6704	+2·8598
29	64·30	32·93	·36	35·695	248·8538	2·8633
Dec. 1	20·03	333·40	·38	35·910	249·0371	2·8668
3	335·74	273·86	·40	36·131	249·2204	2·8703
5	291·44	214·30	·42	36·357	249·4037	2·8738
7	247·12	154·72	−0·44	36·588	249·5870	+2·8772
9	202·78	95·12	·45	36·823	249·7703	2·8806
11	158·43	35·51	·47	37·063	249·9536	2·8840
13	114·06	335·88	·48	37·307	250·1369	2·8873
15	69·68	276·24	·50	37·554	250·3201	2·8906
17	25·28	216·58	−0·51	37·804	250·5033	+2·8939
19	340·86	156·91	·52	38·058	250·6865	2·8972

Greenwich Noon.		Angle of Position of ♃'s Axis. P	L–O.	Diff.	B	Annual Parallax. A–L.	Apparent Diameter. Equat.	Phase.	Polar.
1892.		°	°		°	°	"	"	"
Dec.	21	·658	239·809	89	2·699	11·059	42·27	·39	39·55
	23	·669	239·898	102	2·692	11·153	41·98	·40	39·29
	25	·681	240·000	115	2·685	11·234	41·70	·40	39·02
	27	335·695	240·115	128	+2·678	+11·302	41·42	0·40	38·76
	29	·711	240·243	141	2·671	11·357	41·14	·40	38·50
	31	·729	240·384	154	2·665	11·399	40·87	·40	38·24
1893.									
Jan.	2	·748	240·538	166	2·660	11·428	40·60	·40	37·99
	4	·769	240·704	178	2·655	11·445	40·33	·40	37·74
	6	335·792	240·882	190	+2·650	+11·450	40·06	0·40	37·49
	8	·816	241·072	201	2·646	11·443	39·80	·40	37·24
	10	·843	241·273	213	2·642	11·425	39·54	·39	37·00
	12	·871	241·486	225	2·639	11·395	39·29	·39	36·76
	14	·901	241·711	235	2·636	11·354	39·04	·38	36·53
	16	335·933	241·946	246	+2·633	+11·302	38·79	0·38	36·30
	18	335·967	242·192	256	2·631	11·239	38·55	·37	36·07
	20	336·003	242·448	266	2·630	11·166	38·31	·36	35·85
	22	336·040	242·714	276	2·629	11·083	38·08	·36	35·63
	24	336·079	242·990	286	2·628	10·990	37·85	·35	35·42
	26	336·120	243·276	295	+2·628	+10·887	37·62	0·34	35·21
	28	336·164	243·571	304	2·628	10·775	37·40	·33	35·00
	30	336·210	243·875	313	2·628	10·654	37·19	·32	34·80
Feb.	1	336·257	244·188	321	2·629	10·524	36·98	·31	34·61
	3	336·306	244·509	330	2·630	10·386	36·77	·30	34·42
	5	336·357	244·839	337	+2·631	+10·239	36·57	0·29	34·23
	7	336·410	245·176	345	2·633	10·084	36·38	·28	34·05
	9	336·465	245·521	353	2·635	9·922	36·19	·27	33·87
	11	336·522	245·874	360	2·637	9·752	36·01	·26	33·70
	13	336·581	246·234	367	2·640	9·574	35·83	·25	33·53
	15	336·642	246·601	374	+2·643	+ 9·390	35·65	0·24	33·36
	17	336·706	246·975	381	2·646	9·199	35·48	·23	33·20
	19	336·772	247·356	387	2·649	9·001	35·32	·22	33·05
	21	336·839	247·743	393	2·653	8·797	35·16	·22	32·90
	23	336·908	248·136	398	2·657	8·587	35·00	·20	32·76
	25	336·980	248·534	404	+2·661	+ 8·371	34·85	0·19	32·62
	27	337·054	248·938	410	2·665	8·150	34·71	·18	32·48
Mar.	1	337·130	249·348		2·670	7·923	34·57	·17	32·35

Greenwich Noon.		Longitude of ♃'s Central Meridian (877°·90) I.	(870°·27) II.	Corr. for Phase.	Light-time.	A−O.	B
1892.		°	°	°	m	°	°
Dec.	21	296·43	97·22	·53	38·314	250·8697	2·9004
	23	251·99	37·51	·54	38·572	251·0529	2·9036
	25	207·53	337·79	·55	38·833	251·2361	2·9067
	27	163·05	278·06	−0·56	39·095	251·4193	+2·9098
	29	118·56	218·31	·56	39·358	251·6025	2·9129
	31	74·06	158·55	·57	39·623	251·7856	2·9160
1893.							
Jan.	2	29·55	98·78	·57	39·888	251·9687	2·9190
	4	345·02	38·99	·57	40·154	252·1519	2·9220
	6	300·48	339·19	−0·57	40·420	252·3350	+2·9250
	8	255·92	279·38	·57	40·686	252·5181	2·9279
	10	211·36	219·56	·57	40·952	252·7012	2·9308
	12	166·79	159·73	·56	41·217	252·8843	2·9337
	14	122·20	99·88	·56	41·482	253·0674	2·9366
	16	77·60	40·02	−0·56	41·746	253·2504	+2·9395
	18	33·00	340·16	·55	42·008	253·4334	2·9423
	20	348·38	280·29	·54	42·269	253·6164	2·9451
	22	303·76	220·40	·53	42·528	253·7994	2·9478
	24	259·13	160·51	·53	42·785	253·9824	2·9505
	26	214·49	100·61	−0·52	43·040	254·1654	+2·9531
	28	169·84	40·70	·51	43·292	254·3484	2·9557
	30	125·18	340·79	·49	43·541	254·5314	2·9583
Feb.	1	80·52	280·87	·48	43·788	254·7143	2·9609
	3	35·85	220·94	·47	44·032	254·8972	2·9635
	5	351·17	160·01	−0·46	44·272	255·0801	+2·9661
	7	306·49	101·07	·44	44·509	255·2630	2·9686
	9	261·80	41·12	·43	44·743	255·4459	2·9710
	11	217·11	341·17	·41	44·972	255·6287	2·9734
	13	172·41	281·21	·40	45·198	255·8115	2·9758
	15	127·71	221·25	−0·38	45·420	255·9943	+2·9782
	17	83·00	161·28	·37	45·637	256·1771	2·9805
	19	38·29	101·31	·35	45·850	256·3599	2·9828
	21	353·58	41·34	·34	46·058	256·5427	2·9851
	23	309·86	341·37	·32	46·261	256·7255	2·9873
	25	264·14	281·39	−0·31	46·460	256·9082	+2·9895
	27	219·42	221·41	·29	46·653	257·0909	2·9916
Mar.	1	174·70	161·42	·27	46·841	257·2736	2·9937

The differences of successive values of the longitudes of ♃'s central meridian vary for I. between 1755°·28 and 1756°·09, and for II. between 1740°·01 and 1740°·83.

The following is a list of Greenwich mean times, when the zero-meridian in the assumed two systems of longitudes will pass the middle of the illuminated disc. The times between successive passages vary for I. between $9^h\ 50^m·40$ and $50^m·67$, and for II. between $9^h\ 55^m·58$ and $55^m·85$.

1892.	I. (877°·90) h m	II. (870°·27) h m		I. (877°·90) h m	II. (870°·27) h m
July 31	9 4·7	4 25·1	Aug. 15	23 2·5	21 39·6
	18 55·2	14 20·8	16	8 53·0	7 35·3
Aug. 1	4 45·7	10 12·1		18 43·2	17 30·9
	14 36·2	20 7·7	17	4 33·9	3 26·5
2	10 17·1	6 3·4		14 24·3	13 22·2
	20 7·6	15 59·0	18	10 5·2	9 13·4
3	5 58·1	11 50·4		19 55·7	19 9·0
	15 48·5	21 46·0	19	5 46·1	5 4·7
4	11 29·5	7 41·7		15 36·6	15 0·3
	21 20·0	17 37·3	20	11 17·5	10 51·6
5	7 10·4	13 28·6		21 7·9	20 47·2
	17 0·9	23 24·3	21	6 58·4	6 42·8
6	12 41·9	9 19·9		16 48·8	16 38·4
	22 32·3	19 15·6	22	12 29·7	12 29·7
7	8 22·8	5 11·2		22 20·1	22 25·3
	18 13·3	15 6·9	23	8 10·6	8 20·9
8	4 3·7	10 58·1		18 1·0	18 16·5
	13 54·2	20 53·8	24	3 51·5	4 12·2
9	9 35·1	6 49·4		13 41·9	14 7·8
	19 25·6	16 45·1	25	9 22·8	9 59·0
10	5 16·1	12 36·3		19 13·2	19 54·6
	15 6·5	22 32·0	26	5 3·7	5 50·2
11	10 47·5	8 27·6		14 54·1	15 45·8
	20 37·9	18 23·3	27	10 35·0	11 37·1
12	6 28·4	4 18·9		20 25·4	21 32·7
	16 18·8	14 14·5	28	6 15·9	7 28·3
13	11 59·8	10 5·8		16 6·3	17 23·9
	21 50·2	20 1·5	29	11 47·2	13 15·1
14	7 40·7	5 57·1		21 37·6	23 10·7
	17 31·1	15 52·7	30	7 28·0	9 6·3
15	13 12·1	11 44·0		17 18·5	19 1·9

1892.	I. (877°·90) h m	II. (870°·27) h m		I. (877°·90) h m	II. (870°·27) h m
Aug. 31	3 8·9	4 57·5	Sept. 19	9 38·6	5 35·0
	12 59·3	14 53·2		19 29·0	15 30·6
Sept. 1	8 40·2	10 44·4	20	5 19·5	11 21·7
	18 30·6	20 40·0		15 9·9	21 17·3
2	4 21·0	6 35·6	21	10 50·7	7 12·9
	14 11·5	16 31·2		20 41·1	17 8·5
3	9 52·3	12 22·4	22	6 31·5	3 4·1
	19 42·7	22 18·0		16 21·9	12 59·7
4	5 33·2	8 13·6	23	12 2·7	8 50·8
	15 23·6	18 9·2		21 53·1	18 46·4
5	11 4·5	4 4·8	24	7 43·5	4 42·0
	20 54·9	14 0·4		17 33·9	14 37·6
6	6 45·3	9 51·6	25	3 24·4	10 28·7
	16 35·7	19 47·2		13 14·8	20 24·3
7	12 16·6	5 42·8	26	8 55·6	6 19·9
	22 7·0	15 38·4		18 46·0	16 15·5
8	7 57·4	11 29·6	27	4 36·4	12 6·6
	17 47·8	21 25·2		14 26·8	22 2·2
9	3 38·3	7 20·8	28	10 7·6	7 57·8
	13 28·7	17 16·4		19 58·0	17 53·4
10	9 9·5	3 12·0	29	5 48·4	3 49·0
	18 59·9	13 7·6		15 38·8	13 44·5
11	4 50·4	8 58·8	30	11 19·6	9 35·7
	14 40·8	18 54·4		21 10·1	19 31·3
12	10 21·6	4 49·9	Oct. 1	7 0·5	5 26·7
	20 12·0	14 45·5		16 50·9	15 22·5
13	6 2·4	10 36·7	2	2 41·3	11 13·6
	15 52·9	20 32·3		12 31·7	21 9·2
14	11 33·7	6 27·9	3	8 12·5	7 4·8
	21 24·1	16 23·5		18 2·9	17 0·4
15	7 14·5	12 14·7	4	3 53·3	2 55·9
	17 4·9	22 10·3		13 43·7	12 51·5
16	12 45·8	8 5·8	5	9 24·5	8 42·7
	22 36·2	18 1·4		19 14·9	18 38·3
17	8 26·6	3 57·0	6	5 5·2	4 33·8
	18 17·0	13 52·6		14 55·7	14 29·4
18	4 7·4	9 43·8	7	10 36·5	10 20·6
	13 57·8	19 39·4		20 26·9	20 16·2

	I.	II.		I.	
	(877°·90)	(870°·27)		(877°·90)	(870°·27)
1892.	h m	h m		h m	h m
Oct. 8	6 17·3	6 11·8	Oct. 26	7 15·8	10 57·9
	16 7·8	16 7·3		17 6·2	20 53·6
9	1 58·2	2 2·9	27	2 56·7	6 49·2
	11 48·6	11 58·5		12 47·1	16 44·8
	21 39·0	21 54·1	28	8 28·0	2 40·4
10	7 29·4	7 49·7		18 18·4	12 36·0
	17 19·8	17 45·3	29	4 8·9	8 27·3
11	3 10·2	3 40·9		13 59·3	18 22·9
	13 0·6	13 36·4	30	9 40·2	4 18·5
12	8 41·4	9 27·6		19 30·6	14 13·1
	18 31·9	19 23·2	31	5 21·1	10 5·4
13	4 22·3	5 18·9		15 11·5	20 1·0
	14 12·7	15 14·5	Nov. 1	10 52·4	5 56·6
14	9 53·5	11 5·6		20 42·9	15 52·2
	19 43·9	21 1·1	2	6 33·3	1 47·9
15	5 34·3	6 56·7		16 23·8	11 43·5
	15 24·7	16 52·3	3	2 14·2	7 34·8
16	1 15·2	2 47·9		12 4·7	17 30·4
	11 5·6	12 43·5	4	7 45·6	3 26·0
	20 56·0	22 39·1		17 36·1	13 21·6
17	6 46·4	8 34·7	5	3 26·5	9 12·9
	16 36·8	18 30·3		13 17·0	19 8·6
18	2 27·2	4 25·9	6	8 57·9	5 4·2
	12 17·7	14 21·5		18 48·4	14 59·8
19	7 58·5	10 12·7	7	4 38·8	10 51·1
	17 48·9	20 8·3		14 29·3	20 46·8
20	3 39·3	6 3·9	8	10 10·2	6 42·4
	13 29·8	15 59·5		20 0·7	16 38·0
21	9 10·6	11 50·7	9	5 51·1	2 33·7
	19 1·0	21 46·3		15 41·6	12 29·3
22	4 51·5	7 41·9	10	1 32·0	8 20·6
	14 41·9	17 37·5		11 22·5	18 16·3
23	10 22·8	3 33·1	11	7 3·6	4 11·9
	20 13·2	13 28·7		16 54·0	14 7·6
24	6 3·6	9 19·9	12	2 44·5	9 58·9
	15 54·0	19 15·5		12 35·0	19 54·6
25	1 44·5	5 11·1	13	8 16·0	5 50·2
	11 34·9	15 6·7		18 6·4	15 45·9

1892.		I. (877°·90)	II. (870°·27)			I. (877°·90)	II. (870°·27)
		h m	h m			h m	h m
Nov.	14	3 56·9	1 41·5	Dec.	3	0 40·4	2 23·2
		13 47·4	11 37·2			10 31·0	12 18·9
	15	9 28·4	7 28·5		4	6 12·1	8 10·4
		19 18·9	17 24·2			16 2·6	18 6·1
	16	5 9·4	3 19·8		5	1 53·1	4 1·8
		14 59·9	13 15·5			11 43·7	13 57·5
	17	10 40·8	9 6·9		6	7 24·8	9 49·0
		20 31·3	19 2·5			17 15·3	19 44·7
	18	6 21·8	4 58·2		7	3 5·9	5 40·4
		16 12·3	14 53·9			12 56·4	15 36·1
	19	2 2·8	0 49·6		8	8 37·5	1 31·9
		11 53·3	10 45·2			18 28·1	11 27·6
	20	7 34·3	6 36·6		9	4 18·6	7 19·1
		17 24·8	16 32·3			14 9·2	17 14·8
	21	3 15·3	2 28·0		10	9 50·3	3 10·5
		13 5·8	12 23·6			19 40·9	13 6·3
	22	8 46·8	8 15·0		11	5 31·4	8 57·7
		18 37·4	18 10·7			15 22·0	18 53·5
	23	4 27·9	4 6·4		12	1 12·6	4 49·2
		14 18·4	14 2·1			11 3·1	14 45·0
	24	9 59·4	9 53·4		13	6 44·2	0 40·7
		19 49·1	19 49·1			16 34·8	10 36·5
	25	5 40·4	5 44·8		14	2 25·4	6 27·9
		15 30·9	15 40·5			12 15·9	16 23·7
	26	1 21·5	1 36·2		15	7 57·1	2 19·4
		11 12·0	11 31·9			17 47·6	12 15·2
	27	6 53·0	7 23·3		16	3 38·2	8 6·7
		16 43·5	17 19·0			13 28·8	18 2·4
	28	2 34·1	3 14·7		17	9 9·9	3 58·2
		12 24·6	13 10·4			19 0·5	13 53·9
	29	8 5·6	9 1·8		18	4 51·1	9 45·4
		17 56·2	18 57·5			14 41·7	19 41·2
	30	3 46·7	4 53·2		19	0 32·2	5 36·9
		13 37·2	14 48·9			10 22·8	15 32·7
Dec.	1	9 18·3	10 40·3		20	6 4·0	1 28·5
		19 8·8	20 36·1			15 54·6	11 24·2
	2	4 59·4	6 31·8		21	1 45·1	7 15·8
		14 49·9	16 27·5			11 35·7	17 11·5

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
1892.	h m	h m		h m	h m
Dec. 22	7 16·9	3 7·3	Jan. 11	9 36·7	9 40·8
	17 7·5	13 3·0	12	5 17·9	5 32·4
23	2 58·1	8 54·6		15 8·5	15 28·2
	12 48·7	18 50·3	13	0 59·2	1 24·0
24	8 29·8	4 46·1		10 49·8	11 19·8
	18 20·4	14 41·9	14	6 31·1	7 11·4
25	4 11·0	0 37·7	15	2 12·3	3 3·1
	14 1·6	10 33·4		12 3·0	12 58·9
26	9 42·8	6 25·0	16	7 44·2	8 50·5
	19 33·4	16 20·7	17	3 25·5	4 42·1
27	5 24·0	2 16·5		13 16·1	14 37·9
	15 14·6	12 12·3	18	8 57·4	10 29·6
28	1 5·2	8 3·9	19	4 38·7	6 21·2
	10 55·8	17 59·6		14 29·3	16 17·0
29	6 37·0	3 55·4	20	0 19·9	2 12·8
	16 27·6	13 51·2		10 10·6	12 8·6
30	2 18·2	9 42·8	21	5 51·9	8 0·3
	12 8·8	19 38·5	22	1 33·1	3 51·9
31	7 50·0	5 34·3		11 23·8	13 47·7
	17 40·6	15 30·1	23	7 5·1	9 39·4
			24	2 46·4	5 31·0
1893.				12 37·0	15 26·9
Jan. 1	3 31·3	1 25·9	25	8 18·3	11 18·5
	13 21·9	11 21·8	26	3 59·6	7 10·2
2	9 3·1	7 13·3	27	9 31·5	12 57·6
3	4 44·3	3 4·8	28	5 12·8	8 49·3
	14 34·9	13 0·6	29	0 54·1	4 41·0
4	10 16·1	8 52·1		10 44·8	14 36·8
5	5 57·3	4 43·8	30	6 26·1	10 28·4
	15 48·0	14 39·6	31	2 7·4	6 20·1
6	1 38·6	0 35·4	Feb. 1	7 39·3	12 7·6
	11 29·2	10 31·2	2	3 20·6	7 59·2
7	7 10·4	6 22·8	3	8 52·6	3 50·9
	17 1·1	16 18·6	4	4 33·9	9 38·4
8	2 51·7	2 14·4	5	10 5·9	5 30·1
	12 42·3	12 10·2	6	5 47·2	11 17·6
9	8 23·5	8 1·8	7	1 28·5	7 9·3
10	4 4·8	3 53·4	8	7 0·5	3 1·0
	13 55·4	13 49·2			

1893.	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
	h m	h m		h m	h m
Feb. 9	2 41·8	8 48·5	Feb. 20	4 29·7	3 0·4
10	8 13·8	4 40·2	21	10 1·7	8 48·0
11	3 55·1	10 27·7	22	5 43·1	4 39·7
12	9 27·1	6 19·4	23	1 24·4	10 27·2
13	5 8·4	12 6·9	24	6 56·4	6 18·9
14	0 49·8	7 58·6	25	2 37·8	2 10·6
15	6 21·8	3 50·3		12 28·4	12 6·5
16	2 3·1	9 37·8	26	8 9·8	7 58·2
17	7 35·1	5 29·5	27	3 51·1	3 49·9
18	3 16·4	11 17·1	28	9 23·1	9 37·4
19	8 48·4	7 8·8	Mar. 1	5 4·5	5 29·1

On page 367 of vol. xli. the corrections may be found which, when applied to the longitudes of ♃'s central meridian, given in the ephemerides for the oppositions from 1875 to 1880, reduce them to the system of longitudes and the daily rate of rotation 870°·42 adopted in the ephemeris for 1881–82, and continued for the succeeding two oppositions. This rate of rotation represented the average motion of the great reddish spot during the first years of its appearance. In consequence of the reported fading away of the spot the system of longitudes referring to it was abandoned in the ephemeris for 1884–85, and another system substituted, which was better adapted for the more quickly rotating equatorial spot, but the system referring to the great spot was re-introduced as system II. in the ephemeris for 1885–86, with the altered rate 870°·31, and as the motion continued to slacken the rate was reduced to 870°·27 in the next ephemeris, and has since been employed without alteration, the zero-meridian, however, being repeatedly shifted 10°. In order to reduce the longitudes of ♃'s central meridian, deduced from the ephemerides, to the system of the present ephemeris, the following corrections must be applied:—

	Corr.	1883.	Corr.	1883.	Corr.
1882. Aug. 2	° +31·6	Feb. 28	° + 0·1	1883. Dec. 25	° −44·9
Sept. 1	27·1	Mar. 30	− 4·4	1884. Jan. 24	−49·4
Oct. 1	22·6	Apr. 29	− 8·9	Feb. 23	−53·9
31	18·1	May 29	−13·4	Mar. 24	−58·4
Nov. 20	13·6	Sept. 26	−31·4	Apr. 23	−62·9
Dec. 30	+ 9·1	Oct. 26	−35·9	May 23	−67·4
1883. Jan. 29	+ 4·6	Nov. 25	−40·4	June 22	−71·9

For 1884–85 the longitudes of ♃'s central meridian, corresponding to the present ephemeris, may be deduced from the following list:—

1884.			1885.			1885.		
Oct.	20	110°30	Jan.	13	284°81	Apr.	13	137°15
	25	141·21		18	316·81		18	168·25
	30	172·18		23	348·84		23	199·25
Nov.	4	203·21		28	20·89		28	230·16
	9	234·31	Feb.	2	52·96	May	3	260·99
	14	265·48		7	85·03		8	291·74
	19	296·71		12	117·09		13	322·41
	24	328·01		17	149·13		18	353·01
	29	359·39		22	181·13		23	23·54
Dec.	4	30·83		27	213·09		28	54·01
	9	62·35	Mar.	4	244·99	June	2	84·44
	14	93·93		9	276·81		7	114·81
	19	125·59		14	308·56		12	145·14
	24	157·31		19	340·23		17	175·43
	29	189·10		24	11·81		22	205·69
1885.				29	43·29		27	235·91
Jan.	3	220·95	Apr.	3	74·67	July	2	265·11
	8	252·85		8	105·96		7	296·30

The differences of successive values vary between 4350°·19 and 4352°·07. The correction for phase is to be found in vol. xliv. p. 450. The longitudes of Dr. Terby's observations, made during this period, have been deduced from an ephemeris corresponding to those for 1887 and 1888, and must be increased 10°.

The corrections for the succeeding ephemerides are:—

	Corr.		Corr.
1885 Nov. 14	+ 10°0	1886 Dec. 9 to 1887 Sept. 5	+ 10°
1886 Jan. 13	+ 7·6	1887 Dec. 24 to 1888 Sept. 19	+ 10°
Mar. 14	+ 5·2	1889 Feb. 26 to Oct. 24	No corr.
May 13	+ 2·8	1890 Mar. 23 to Dec. 18	No corr.
July 12	+ 0·4	1891 Apr. 17 to 1892 Feb. 11	−10°.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LII. JUNE 10, 1892. No. 8

E. B. KNOBEL, President, in the Chair.

The Rev. James Baikie, Glenview Terrace, Barterholm, Paisley, N.B.;
John Dansken, F.S.I., 4 Eldon Terrace, Partick, Glasgow;
Henry Daniel McCarthy, 5 Promenade, Cheltenham; and
Martin Charles Sharp, M.A., 5 Portman Street, Portman Square, W.,
were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

John A. Brashear, Astronomical and Physical Instrument Maker, Allegheny, Pennsylvania, U.S.A. (proposed by W. H. Maw);
Walter William Bryant, Assistant, Royal Observatory, Greenwich, Seymour Cottage, Conduit Vale, Blackheath, S.E. (proposed by W. H. M. Christie);
Captain James Fisher, 7 Fenchurch Avenue, E.C. (proposed by Capt. P. Thompson);
Thomas Charlton Hudson, Assistant, Royal Observatory, Greenwich, 88 King George Street, West Greenwich, S.E. (proposed by W. H. M. Christie);
Francis R. Wardle, Banker, 43 Moorgate Street, E.C. (proposed by H. B. Chamberlin).

Seventy-six presents were announced as having been received since the last meeting, including, amongst others,

J. Woodbridge Davis, The Dynamics of the Sun, presented by Mr. G. F. Chambers; Description of the Star Camera at the Sydney Observatory, and enlarged photograph of the region surrounding the η *Argûs* nebula, presented by Mr. H. C. Russell; Observations of Double Stars, part 2, and the orbit of *Iapetus*, by Asaph Hall, presented by the author; H. Jacoby, The Rutherfurd photographic measures of the group of the *Pleiades*, presented by the author; First and Second Reports of the Solar Physics Committee, presented by the Committee; Tables de Logarithmes à huit décimales, presented by the French War Office; S. Glasenapp, Mesures d'étoiles doubles, presented by the author; Two lantern slides of the region surrounding Nova *Aurigæ*, presented by the Lick Observatory; Photographs of double stars (lantern slide) to illustrate method of determining star magnitudes by photography, presented by Mr. W. E. Wilson; Photographs of the globular cluster 15 M *Pegasi*, and of the nebula H V 15, near 52 *Cygni*, presented by Mr. Roberts.

The Opposition of Mars, 1892. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

A circular has been recently issued from the Washington Observatory, in which a scheme is formulated for meridian observations of *Mars* from 1892, June 20, to September 23, for a redetermination of the constant of solar parallax.

The horizontal equatorial parallax of *Mars* at the opposition of 1892 reaches a limit of $23''\cdot4$; but the planet has a considerable south declination, and this will somewhat reduce the combined parallactic displacements available from observations made at the northern and southern observatories, increase the probable errors of the observations, and render it more difficult to completely eliminate the effects of refraction errors by the observations of comparison stars than was the case in 1862 and 1877; but a result of considerable weight might probably be obtained if the co-operation of several southern and northern observatories could be secured, and the same comparison stars regularly observed at all the stations under the same instrumental conditions as the planet.

But the necessary co-operation has been rendered doubtful by the shortness of the notice given, which renders any modification of details difficult, and by the recommendation of a scheme of observation of a somewhat complicated character.

The method of determining the constant of solar parallax from meridian observations of *Mars* has always appeared to me one of the most powerful available for the purpose, and on the following grounds, viz.:—

1. The observations can be made by experienced observers, with instruments which they are accustomed to use, in the course of their regular duties, without the necessity of any change of methods of observation, and without any unusual strain or excitement.

2. Any outstanding errors of the refraction tables in use can be practically eliminated by the observation of comparison stars of greater and lesser zenith distance than the planet on each night at all the stations.

3. Any outstanding errors of division, or errors of flexure corrections, may be eliminated in mean results in a similar manner.

4. The observations can be made by so many different observers, with so many different instruments, that the effects of any ordinary systematic errors of meridian observations need not be feared.

5. The observations can be repeated at frequent intervals without any great disorganisation of the regular work of the meridian observatories.

6. The available parallactic displacements of *Mars* at favourable oppositions are so large, that an error of one per cent. in the adopted value of the constant of solar parallax will lead to discordances between theory and observation of more than a quarter of a second of arc, a quantity which much exceeds the ordinary accidental errors to be expected in the mean results derived from the observations which may be obtained at a single opposition.

7. The required constant of solar parallax is derived from a discussion of observations made under the same conditions, with the same instruments, and by the same observers, as those employed for the determination of the other constants which appear in the theoretical expressions in combination with the constant of solar parallax.

In the Washington Circular it is proposed to fix the position of the planet *Mars* by the method, introduced by Dr. Winnecke in 1862, of equal segments.

The adoption of this method requires that a system of parallel wires, movable by the declination-screw, should be placed in the eye-pieces at a distance apart somewhat less than the diameter of the planet at the opposition. This distance would in 1892 be about 16″. But no such wires are usually found in the eye-pieces of the transit-circles of meridian observatories; and the method of equal segments is not one with which meridian observers, in general, are familiar.

It is quite possible that observers who have had much experience with the method of equal segments might fix the position of the centre of *Mars* by this method with a slightly greater accuracy than by the more usual method of contacts; but it is at least very doubtful whether such will be the case with respect to observers who have had experience with the method of contacts, but not with that of equal segments; and

the introduction of the two wires to fix the position of the centre of the planet renders it absolutely necessary that the observations of the comparison stars should be equally distributed between the two wires on each night of observation, a condition which in practice cannot always be secured, from passing clouds.

But in the Washington Circular it is also proposed that a reflecting prism should be mounted outside the eye-piece, and that the observations of *Mars* and stars should be made half with, and half without, the use of the reflecting prism.

I fear that attempts to carry out this scheme will lead to greater systematic errors in fixing the relative differences in North Polar Distance between the centre of *Mars* and the comparison stars, from a want of symmetrical distribution of the observations of the stars between the two wires, than can be compensated for by any possible increase of accuracy from the use of the two wires and the reflecting prism.

The removal of the eye-piece for the insertion of a new pair of wires, the redetermination of the intervals and inclination of the wires, and the loss of observations which this will cause, must disorganise the work of an active meridian observatory to an extent which is hardly likely to be sanctioned, unless some very positive advantages are certain to be secured by the adoption of the system of parallel wires.

The results obtained in 1862 and 1877 did not indicate the existence of any systematic differences between the observations made with the pair of wires and the single wire when the observations of the comparison stars were properly distributed between the wires. I propose, therefore, to observe *Mars* and the comparison stars in the usual way with the single wire, and without the reflecting prism; and I hope that any directors of the southern observatories who may not be prepared to adopt the Washington scheme will yet observe the planet and comparison stars in the same way.

Observing List from Washington Circular.

From June 20 to July 26.

Object.	Mag.	R.A. h m s	δ ° ′
O. Arg. S. 20970	7·0	20 50 38	−22 25·1
η Capricorni	5·0	20 58 15	20 16·8
27 Capricorni	6·5	21 3 23	20 59·2
φ Capricorni	5·5	21 9 30	21 5·9
Lacaille 8851	6·0	21 29 5	23 56·2
41 Capricorni	5·8	21 35 51	23 45·0
D.M. − 20° 6923	7·5	21 41 42	20 4·3
Lalande 42700	7·2	21 49 37	21 38·8

From July 27 to August 10.

Object.	Mag.	R.A. h m s	δ ° ′
Lacaille 8463	6·2	20 23 11	−22 45·1
„ 8506	7·0	20 31 41	24 36·2
17 Capricorni	5·9	20 39 54	21 54·3
Lacaille 8612...	7·0	20 46 42	24 11·2
„ 8813...	6·0	21 19 36	24 17·2
„ 8832...	7·8	21 24 12	25 40·0
„ 8851...	6·0	21 29 5	23 56·2
O. Arg. S. 21562	7·8	21 35 24	22 25·3

From August 11 *to September* 23.

Object.	Mag.	R.A. h m s	δ ° ′
O. Arg. S. 20429	7·0	20 15 6	−23 49·1
Lacaille 8463	6·2	20 23 11	22 45·1
„ 8506	7·0	20 31 41	24 36·2
17 Capricorni	5·9	20 39 54	21 54·3
Lacaille 8734	7·0	21 7 1	25 17·2
Lalande 41404	7·5	21 14 32	22 50·7
ζ Capricorni	4·0	21 20 30	22 52·8
37 Capricorni	6·2	21 28 47	20 34·0

List of the Proper Motions in the Line of Sight of Fifty-one Stars. By H. C. Vogel, Foreign Associate.

In continuation of my communication of 1891 December, on the spectrographic method (vol. lii. No. 2) I hereby transmit the definitive results of that investigation, the observations having been meanwhile brought to a close.

The complete discussion of these researches will be given in the *Publicationen des Astrophysikalischen Observatoriums*, Bd. VII. (Engelmann: Leipzig), which will probably appear during this month (June).

No.	Star.	Epoch.	No. of Plates.	Velocity relative to Sun. (English Miles) Vogel.	Scheiner.	Mean.
1	α Andromedæ	1889·93	2	+ 1·2	+ 4·4	+ 2·8
2	β Cassiopeiæ	1889·04	2	+ 0·8	+ 5·6	+ 3·2
3	α Cassiopeiæ	1890·14	2	− 9·3	− 9·7	− 9·5
4	γ Cassiopeiæ	1888·89	2	+ 2·5	− 6·9	− 2·2
5	β Andromedæ	1889·26	2	+ 5·6	+ 8·3	+ 7·0
6	α Ursæ minoris	1888·90	2	−15·8	−16·3	−16·1

No.	Star.	Epoch.	No. of Plates.	Velocity relative to Sun. (English Miles) Vogel.	Scheiner.	Mean.
7	γ Andromedæ	1889·34	2	− 4·9	−11·1	− 8·0
8	α Arietis	1889·69	3	− 9·0	− 9·3	− 9·2
9	β Persei †	1889·94	12	...	...	− 1·0
10	α Persei	1888·93	2	− 6·7	− 6·1	− 6·4
11	α Tauri	1889·16	4	+29·6	+30·7	+30·2
12	α Aurigæ	1888·98	11	+15·4	+15·0	+15·2
13	β Orionis	1889·24	14	+10·9	+ 9·5	+10·2
14	γ Orionis	1890·37	3	+ 8·0	+ 3·4	+ 5·7
15	β Tauri	1889·65	3	+ 5·6	+ 4·4	+ 5·0
16	δ Orionis	1890·07	4	− 0·1	+ 1·3	+ 0·6
17	ε Orionis	1889·00	3	+17·3	+15·6	+16·5
18	ζ Orionis	1889·00	2	+10·7	+ 7·8	+ 9·3
19	α Orionis	1889·32	2	+ 9·7	+11·7	+10·7
20	β Aurigæ †	1890·50	6	−16·0	−18·9	−17·5
21	γ Geminorum	1889·83	4	− 9·7	−10·8	−10·3
22	α Canis majoris	1890·09	10	− 8·4 ‡	−12·5	− 9·8
23	α Geminorum *	1889·16	3	−18·4 :	−18·4 :	−18·4 :
24	α Canis minoris	1889·68	3	− 4·9	− 6·5	− 5·7
25	β Geminorum	1889·06	2	+ 1·2	+ 0·2	+ 0·7
26	α Leonis	1889·22	2	− 5·3	− 6·1	− 5·7
27	γ Leonis	1889·76	2	−22·7	−25·2	−24·0
28	β Ursæ majoris	1889·39	2	−18·8	−17·6	−18·2
29	α Ursæ majoris	1889·11	4	− 6·4	− 7·9	− 7·2
30	δ Leonis	1889·94	3	− 9·3	− 8·6	− 8·9
31	β Leonis	1889·59	3	− 8·6	− 6·5	− 7·6
32	γ Ursæ majoris	1889·40	2	−18·6	−14·4	−16·5
33	ε Ursæ majoris	1889·39	2	−21·3	−16·2	−18·8
34	α Virginis †	1890·34	27	...	...	− 9·2
35	ζ Ursæ majoris * †	1890·33	8	−20·2	−18·5	−19·4
36	η Ursæ majoris	1889·83	2	−17·8	−14·8	−16·3
37	α Bootis	1889·57	6	− 4·4	− 5·2	− 4·8
38	ε Bootis	1889·36	2	−10·4	− 9·7	−10·1
39	β Ursæ minoris	1889·24	4	+ 8·9	+ 8·8	+ 8·9
40	β Libræ	1889·34	1	− 6·0 :		− 6·0 :
41	α Coronæ Borealis	1890·91	5	+19·7	+20·0	+19·9
42	α Serpentis	1889·36	1	+14 : :		+14 : :

* Brightest component. † Motion of the system. ‡ Weight 2.

No.	Star.	Epoch.	No. of Plates.	Velocity relative to Sun. (English Miles) Vogel.	Scheiner.	Mean.
43	β Herculis	1889·46	2	−21·3	−22·6	−22·0
44	α Ophiuchi	1889·09	2	+12·9	+10·9	+11·9
45	α Lyræ	1889·64	8	− 8·7	−10·2	− 9·5
46	α Aquilæ	1888·81	3	−24·7	−21·1	−22·9
47	γ Cygni	1888·93	2	− 3·6	− 4·3	− 4·0
48	α Cygni	1888·99	4	− 3·7	− 6·2	− 5·0
49	ε Pegasi	1888·81	2	+ 4·6	+ 5·4	+ 5·0
50	β Pegasi	1889·90	1	+ 4·1 :		+ 4·1 :
51	α Pegasi	1888·81	2	+ 1·1	+ 0·4	+ 0·8

Greatest observed velocity ... +30·2 miles (α Tauri); −24·0 miles (γ Leonis).
Average velocity ... ... 10·4 miles.
No. of stars with positive velocity greater than 10·4 miles 7
No. of stars with negative velocity greater than 10·4 miles 11
Average probable error of the measurements for a single plate and one observer ... ... ±1·6 mile

: denotes less certain, and :: uncertain.

Potsdam, Royal Observatory:
1892 *June.*

Photographs of the Region of the Globular Cluster 15 M Pegasi. By Isaac Roberts, F.R.S.

Three photographs of the region of 15 M *Pegasi*, R.A. $21^h\ 25^m$, declination 11° 41′ N., have been taken with the 20-inch reflector, the first on 1890 November 4, with an exposure of two hours, the second on 1891 October 4, with an exposure of thirty minutes, and the third on 1891 November 27, with an exposure of sixty minutes.

The enlarged photographs now presented have been made from the first of the negatives with the exposure of two hours, and the scales of the enlargements are one millimetre to four seconds of arc in one, and one millimetre to twenty-four seconds in the other.

Sir John Herschel in his observations of nebulæ and clusters of stars, No. 2120, writes of M 15 as "a magnificent globular cluster; comes up to a perfect blaze in the centre, like a protuberance or nipple, not the condensation of a homogeneous globe; it has straggling streams of stars, as it were, drawing to

a centre, is irregularly round, very faint stars 15 magnitude all distinct, but running together into a blaze in the middle, 4′ or 5′ diameter."

Lord Rosse records four observations of the cluster between the years 1852 and 1876, and he states that the stars are bright and faint, and sharply distinct from each other; nucleus a little excentric from the middle. These descriptions convey but little information that is of scientific value, and there are no drawings for comparison with the photographs.

A well-executed print from an enlargement of a photograph of this cluster is given in the volume of the *Specola Vaticana* for 1891, and I have compared it with these photographs, and give the following results:—The stars are easily identified on the respective photographs, but the extent of the nebulosity differs largely. On the Vatican print it can be measured to about sixty-five seconds of arc in diameter round the nucleus, but on my print it measures about 200 seconds of arc. The Vatican print does not cover the whole of the cluster, and in that respect these prints convey a fuller idea of the magnificent proportions of the object. Several rings of stars are visible round the margin of the cluster, and there are also branches, extending in various directions.

Now that we have accurate records of the position and magnitude of every star in the cluster, it is obvious that a few years hence it will be possible to unravel the mysteries that present themselves to us in this and in several other similar star clusters.

Photograph of the Nebula H *V* 15, *near* 52 *Cygni.* By Isaac Roberts, F.R.S.

The enlarged photograph now presented was made from a negative, taken with the 20-inch reflector, on 1891 September 28, and exposure of the plate during four hours of clear sky, and represents the region round the double star, 52 *Cygni*, R.A. 20^{h} 41^{m}, declination 30° 20′ N., on the following side of which is the remarkable nebula H V 15.

This nebula is thus described by Sir John Herschel in his observations of nebulæ and clusters of stars, No. 2088. The nebula is very long and winding, and runs northward from k (52), full two fields breadth (30′). The nebula extends southwards far beyond k *Cygni*, but is extremely faint; the northern part is pretty bright, and extends to two stars. Northwards from k *Cygni*, 27′, extends a curved tail of nebula of a serpentine form, fading very gradually into two tails forming a fork.* A drawing of the nebula is given in the *Phil. Trans.* R.S., in 1833

* Abridged description.

November, which shows very fairly in its outline parts of the brighter nebulosity, but the photograph clearly shows that these form part of an irregular oval nebula of gigantic dimensions. It is more than two degrees in length from north to south, and forty-seven minutes of arc in breadth on the following side of 52 *Cygni*, which it barely touches by a slight projection. The nebulosity is of a very faint streaky character, excepting that which was seen by Sir John Herschel. The nebula as a whole is not symmetrical, but seems to be made up of detached patches of light covering the large area, and a much longer exposure than four hours will be required to show the connections of these diffused patches of light. It will be observed on examination of the photograph that the stars on the *following* side of 52 *Cygni* are very much more numerous than they are on the *preceding* side. The bright part of the nebula seems to form almost a defined boundary between the stream of the Milky Way stars and those on its *preceding* side. The straight line across 52 *Cygni* was caused by a sudden gust of wind during the exposure of the plate.

Photograph of η Argûs. By H. C. Russell.

I think the photograph sent herewith, which is an enlargement of one of our photographs of *η Argûs*, taken with the star camera and $5\frac{3}{4}$ hours' exposure, will be interesting to the members of our Society. The scale is 12·4 inches = 1°; and it brings out in a satisfactory way most, but not all, that the negative contains. The scale is five-sixths of that adopted by Herschel in the Cape observations, and a comparison of the two is very suggestive. In the denser parts I have counted over 100 stars in a square inch, or more than 3500 stars in a degree, and in some places they run up to 130 in a square inch, upwards of 4500 in a degree, and the enlargement has lost many of the fainter stars visible on the negative. The mottled appearance of the nebula and its vast extent are strikingly brought out. The scale in the original negative is not large enough to divide some of the close groups, hence they appear in the enlargement as one star.

Sydney Observatory:
1892 *April* 11.

Orbit of 9 *Argûs*, β 101. By Professor S. Glasenapp.

(*Letter from Professor S. Glasenapp to S. W. Burnham.*)

The complete measures of 9 *Argûs*, which I have had the honour to receive from you, have enabled me to investigate the orbit of this interesting binary star. I find for this system a period of 40·54 years. The eccentricity is extraordinarily small, being only 0·09.

The following table contains the measures of 9 *Argûs*, made by Dembowski (Δ), the Astronomers at the Cincinnati Observatory (Cin.), Burnham (β), Hall (Hl.) and Schiaparelli (Sp.)

1875·71	289°·4	0″·46	Δ	3n
1878·47	302·6	0·45	Cin	4n
1878·52	301·8	0·46	β	1n
1879·68	306·2	0·38	Hl	2n
1882·21	319·7	0·35	Sp	4n
1883·11	336·2	0·3	β	1n
1889·08	76·4	0·34	β	4n
1890·19	83·0	0·4	Sp	2n
1890·26	84·6	0·31	β	4n
1890·96	88·3	0·36	β	3n
1891·15	94·7	0·3	Sp	1n
1892·05	98·7	0·22	β	3n

From these observations we form the annual means for 1878, 1890, and 1891, assigning to the two measures of distance made by Professor Schiaparelli in 1890 and 1891 a weight equal to one-half, and thus obtain the following normal places:—

1875·71	289°·4	0″·46	1888·26	356°·1	0″·29
78·50	302·2	0·45	89·08	76·4	0·34
79·68	306·2	0·38	90·22	83·8	0·34
82·21	319·7	0·35	91·06	91·5	0·34
83·11	336·2	0·30	92·05	98·7	0·22

By the graphical method we obtain the geometrical elements of the true orbit as follows:—

$\Omega_0 = 116°·6$ $\quad\quad$ $e_0 = 0°·105$

$i_0 = 55·8$ $\quad\quad$ $a_0 = 0''·48$

$\lambda_0 = 252·3$

And then the dynamical elements from the first and last observations:—

$$T_0 = 1843{\cdot}02$$
$$n_0 = +8^{\circ}{\cdot}774$$
$$u_0 = 41{\cdot}03 \text{ years.}$$

We obtain the following corrections to the elements by the method of least squares:—

$$\Delta T = +1{\cdot}00 \text{ years}; \ \Delta n = +0^{\circ}{\cdot}106; \ \Delta \Omega = +0{\cdot}1;$$
$$\Delta i = +3^{\circ}{\cdot}4; \ \Delta\lambda = -1^{\circ}{\cdot}0; \ \Delta e = -0{\cdot}015; \ \Delta a = -0''{\cdot}03.$$

So that the most probable elements of the true orbit of 9 *Argûs* will be:—

$T = 1844{\cdot}02$	$i = 59^{\circ}{\cdot}2$
$u = 40{\cdot}54$ years	$\lambda = 251^{\circ}{\cdot}3$
$n = +8^{\circ}{\cdot}880$	$e = 0{\cdot}090$
$\Omega = 116^{\circ}{\cdot}7$	$a = 0''{\cdot}45$

The comparison of these elements with the observations is given in the following table:—

T	θ_o	θ_c	$\theta_o-\theta_c$	ρ_o	ρ_c	$\rho_o-\rho_c$
	°	°	°	"	"	"
1875·71	289·4	287·5	+1·9	0·46	0·43	+0·03
78·50	302·2	301·1	+1·1	0·45	0·42	+0·03
79·68	306·2	307·4	−1·2	0·38	0·40	−0·02
82·21	319·7	324·9	−5·2	0·35	0·32	+0·03
83·11	336·2	333·7	+2·5	0·30	0·29	+0·01
89·08	76·4	73·6	+2·8	0·34	0·27	+0·07
90·22	83·8	85·4	−1·6	0·34	0·32	+0·02
91·06	91·5	92·1	−0·6	0·34	0·35	−0·01
92·05	98·7	98·7	0·0	0·22	0·38	−0·16

The position of this star for 1880 is:—

$$\left.\begin{array}{l} \alpha = 7^{h}\ 46^{m}\ 13^{s} \\ \delta = -13^{\circ}\ 35' \end{array}\right\}$$

The system has an annual proper motion of $0''{\cdot}345$ in the direction of $195^{\circ}{\cdot}7$. It should receive the attention of astronomers with large telescopes.

Observatoire de l'Université Impériale, St.-Pétersbourg:
1892 *April* 24.

Orbit of the Double Star κ Pegasi A C.
By Professor S. Glasenapp.

(*Communicated by S. W. Burnham.*)

In 1880 Mr. S. W. Burnham, M.A., discovered the duplicity of the large star of the binary *κ Pegasi* ($a = 21^h\ 39^m\!\cdot\!7$, $\delta = +25°\ 8'$ for 1890). The new companion (C) has been observed only by Mr. Burnham and by the late R. Engelmann; no other observations have been published. The following observations have been kindly communicated to me by Mr. S. W. Burnham:—

T	θ	ρ	Observer.
	°	"	
1880·68	137·9	0·27	β 4n
83·02	116·0	0·16	En 1n
84·01	140·0	0·25	En 1n
84·87	104·7	0·22	β 1n
88·78	274·7	0·23	β 3n
89·51	262·3	0·14	β 4n
90·57	187·1	0·10	β 4n
91·61	150·0	0·10	β 3n
91·81	144·6	0·13	β 4n
92·36	135·1	0·17	β 1n

For the investigation of the orbit we take a simple mean of the three observations, made in 1883 and 1884 by Engelmann and Burnham; in this manner we obtain for 1883·97 a mean position $\theta = 120°\ 2$ and $\rho = 0''\!\cdot\!21$. It would be better perhaps to reject the observation of Engelmann made in 1884, but as the value of the measures can be estimated only after the investigation of the orbit, we retain it.

The following table, therefore, embraces all the measured positions:—

T	θ	ρ	T	θ	ρ
	°	"		°	"
1880·68	137·9	0·27	1890·57	187·1	0·10
83·97	120·2	0·21	91·61	150·0	0·10
88·78	274·7	0·23	91·81	144·6	0·13
89·51	262·3	0·14	92·36	135·1	0·17

It is evident that the satellite has described a whole revolution; the elements of the orbit can therefore be determined with satisfactory precision. By the graphical method we very easily obtain the following system of elements:—

$T = 1898{\cdot}8$ $\lambda = 199{\cdot}9$

$U = 11{\cdot}54$ years $(n = -31^\circ{\cdot}196)$ $e = 0{\cdot}28$ $(\phi = 16^\circ{\cdot}26)$

$\Omega = 133^\circ{\cdot}0$ $a = 0''{\cdot}21$

$i = 71^\circ{\cdot}6$

and then the corrections of Ω, i and ϕ, namely: $d\Omega = -7^\circ{\cdot}34$, $di = -5^\circ{\cdot}62$, and $d\phi = -4^\circ{\cdot}723$, so that the most probable system of elements will be

$T = 1898{\cdot}8$ $\lambda = 199{\cdot}90$

$U = 11{\cdot}54$ years $(n = -31^\circ{\cdot}196)$ $e = 0{\cdot}20$ $(\phi = 11^\circ{\cdot}537)$

$\Omega = 125^\circ{\cdot}66$ $a = 0''{\cdot}21$

$i = 65^\circ{\cdot}98$

The comparison of these elements with the observations is given in the following table:—

T	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
	°	°	°	"	"	"
1880·68	137·9	142·8	− 4·9	0·27	0·21	+0·06
83·97	120·2	109·0	+11·2	0·21	0·19	+0·02
88·78	274·7	281·8	− 7·1	0·23	0·14	+0·09
89·51	262·3	252·1	+10·2	0·14	0·10	+0·04
90·57	187·1	184·2	+ 2·9	0·10	0·13	−0·03
91·61	150·0	152·1	− 2·1	0·10	0·17	−0·07
91·81	144·6	148·7	− 4·1	0·13	0·18	−0·05
92·36	135·1	141·1	− 6·0	0·17	0·21	−0·04

The element λ (distance between the node and the periastron) could not be determined with great exactitude, because there are only two observations of the satellite in 1888 and 1889 from which it can be determined.

In the differences between the calculated and observed distances we remark a singular relation; all the distances measured before 1890 are larger than the calculated, and all the distances measured after 1890 are smaller. This might be supposed to indicate defective elements of the orbit, but it may be explained by the fact that the earlier observations were made with smaller telescopes than the later ones, for distances are always measured too great with small telescopes.

The star is very close, and can be observed only with large telescopes; it belongs to the class of binaries of very short period, its period being one of only 11·5 years.

1892 *June* 4.

The Orbit of OΣ 269. By J. E. Gore.

A measure made by Mr. Burnham last year, of this close and difficult double star, discovered by O. Struve in 1844, shows that one revolution had then been nearly completed. I have computed the orbit and find the following provisional elements:—

Elements of OΣ 269.

$P = 47{\cdot}70$ years.	$\Omega = 51^\circ\ 56'$
$T = 1883{\cdot}12$	$\lambda = 45^\circ\ 30'{\cdot}5$
$e = 0{\cdot}0575$	$\mu = +7^\circ{\cdot}547$
$i = 82^\circ\ 48'{\cdot}7$	$a = 0''{\cdot}58$

These elements are remarkable for the high inclination and small eccentricity of the real orbit, an eccentricity very unusual in binary stars. The apparent ellipse I find very much resembles that given by Mr. Burnham in the *Observatory* for 1891 July, but is more elongated.

The following is a comparison between the above elements and the measures used in computing the orbit:—

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
		°	°	°	"	"	"
1844·31	O. Struve	218·0	218·0	0·0	0·33	0·26	+0·07
1846·39	"	223·8	224·2	−0·4	0·39	0·39	0·0
1851·39	"	228·9	230·6	−1·7	0·33	0·59	−0·26
1861·26	"	242·8	242·8	0·0	0·33	0·34	−0·01
1883·41	Engelmann	61·4	60·1	+1·3	0·22	0·36	−0·14
1891·26	Burnham	213·4	213·4	0·0	0·22	0·21	+0·01

On the assumption that the mass of the system is equal to the mass of the Sun, the "hypothetical parallax" would be

$$p = \frac{a}{P^{\frac{2}{3}}} = 0''{\cdot}044$$

According to the Draper Catalogue of Stellar Spectra the spectrum of the star is of the first type (A).

According to Burnham the magnitudes of the components are 7·2 and 7·7. The star is *Lalande* 25074, and its position for 1900 is

R.A. $13^{h}\ 28^{m}{\cdot}3$

Decl. $+35^\circ\ 25'$

On the Formulæ of Reduction to Apparent Places of Close Polar Stars. By F. Folie.

(*Communicated by A. M. W. Downing.*)

In the *Bulletin Astronomique* (February 1888 and seq.) I made some criticisms upon the method proposed by Fabritius for the reduction of close polar stars, and on his demonstration of it, and I exhibited the discordance between the form adopted and the formulæ used in the *Berliner Jahrbuch*, the latter being more correct.

M. Fabritius, in tom. iii. of the *Observations of Kiew*, having again contested my criticisms, and given a new demonstration of his formulæ, I have made a new inquiry on the terms of second order, by a process giving the same form as his own, but with some additional terms.

The importance of the question, and the recent investigation of Mr. Downing on the computation of apparent places for *Polaris* (*Monthly Notices*, lii. 5, p. 378), give me hope that the present lines will be read with interest by astronomers.

The investigation of the terms of the second order is threefold:—

1. Terms of the second order of the nutation.
2. Terms of the second order due to the combination of the nutation and aberration.
3. Terms of the second order of the aberration.

1. *Terms of the Second Order of the Nutation.*

The first of these investigations is the most complicated, and the method I have adopted is a new one. I here give a summary of it.

The equations:—

$$(1)\qquad \begin{aligned} \frac{d\alpha}{dt} &= (\cot \epsilon + \sin \alpha \tan \delta)\frac{d\mu}{dt} - \cos \alpha \tan \delta \frac{d\theta}{dt} \\ \frac{d\delta}{dt} &= \cos \alpha \frac{d\mu}{dt} + \sin \alpha \frac{d\theta}{dt}; \end{aligned}$$

where

$$d\mu = \sin \epsilon d\lambda,$$

and, if α, δ are the mean values of the co-ordinates for the beginning of the year, give the terms of first order:—

$$(2)\qquad \begin{aligned} \Delta_1\alpha &= (\cot \epsilon + \sin \alpha \tan \delta)\Delta\mu - \cos \alpha \tan \delta \Delta\theta \\ \Delta_1\delta &= \cos \alpha \Delta\mu + \sin \alpha \Delta\theta. \end{aligned}$$

To these terms we must add $\delta\Delta_1\alpha$, $\delta\Delta_1\delta$, because in the equation (1) are included the true co-ordinates; so that α, δ are the mean co-ordinates, and $\alpha+\Delta_1\alpha$, $\delta+\Delta_1\delta$ the true ones.

From (1), if ϵ is considered constant, we have

$$\frac{d\delta\Delta_1\alpha}{dt} = \tan\delta\Delta_1\alpha\left(\cos\alpha\frac{d\mu}{dt} + \sin\alpha\frac{d\theta}{dt}\right) + \sin^2\delta\Delta_1\delta\left(\sin\alpha\frac{d\mu}{dt} - \cos\alpha\frac{d\theta}{dt}\right)$$

$$(3) \qquad = \tan\delta\Delta_1\alpha\frac{d\delta}{dt} + \frac{1}{\sin\delta\cos\delta}\Delta_1\delta\left(\frac{d\alpha}{dt} - \cot\epsilon\frac{d\mu}{dt}\right)$$

$$= \tan\delta\frac{\Delta_1\alpha d\delta + \Delta_1\delta d\alpha}{dt} + \cot\delta\Delta_1\delta\frac{d\alpha}{dt} - \frac{2}{\sin 2\delta}\cot\epsilon\Delta_1\delta\frac{d\mu}{dt},$$

and

$$\frac{d\delta\Delta_1\delta}{dt} = -\Delta_1\alpha\left(\sin\alpha\frac{d\mu}{dt} - \cos\alpha\frac{d\theta}{dt}\right) = -\cot\delta\Delta_1\alpha\left(\frac{d\alpha}{dt} - \cot\epsilon\frac{d\mu}{dt}\right).$$

Integrating and neglecting the terms in which $\tan\delta$ and $\sec\delta$ are not included:

$$\delta\Delta_1\alpha = \tan\delta\Delta_1\alpha\Delta_1\delta - \frac{2}{\sin 2\delta}\cot\epsilon\int\Delta_1\delta\frac{d\mu}{dt}$$

$$(4) \qquad = \tan\delta\Delta_1\alpha\Delta_1\delta - \frac{2\cot\epsilon}{\sin 2\delta}\left(\tfrac{1}{2}\cos\alpha\,(\Delta\mu)^2 + \sin\alpha\int\Delta\theta d\mu\right).$$

$$\delta\Delta_1\delta = -\tfrac{1}{2}\cot\delta(\Delta_1\alpha)^2.*$$

If

$$F = -\frac{2\cot\epsilon}{\sin 2\delta}\left(\tfrac{1}{2}\cos\alpha(\Delta\mu)^2 + \sin\alpha\int\Delta\theta d\mu\right),$$ the equation (4) becomes

$$(4') \qquad \delta\Delta_1\alpha = \tan\delta\Delta_1\alpha\Delta_1\delta + F$$

$$\delta\Delta_1\delta = -\tfrac{1}{2}\cot\delta(\Delta_1\alpha)^2,$$

forms of Fabritius with the term F in addition.

2. *Combination of the Nutation and the Annual Aberration.*

The terms of the second order arising from the combination of the nutation and the aberration are in the very convenient forms given by Wagner †; if $\Delta_1\alpha$, $\Delta_1\delta$ are the terms of first order of the nutation, and A_α, A_δ those of the aberration,

$$(5) \qquad \delta A_\alpha = \tan\delta A_\alpha\Delta_1\delta + \frac{2}{\sin 2\delta}A_\delta\Delta_1\alpha;$$

$$\delta A_\delta = -\tfrac{1}{2}\sin 2\delta A_\alpha\Delta_1\alpha.$$

3. *Terms of the Second Order of the Aberration.*

The terms of the second order of the annual aberration may be put in a similar form if we omit the terms in which $\tan^2\delta$ in right

* If this form gives $\delta\Delta_1\delta$ infinite for $\delta = 0$, as M. Fabritius thinks (*Obs. de Kiew*, t. iii.), it is only in appearance; $(\Delta_1\alpha)^2$ is, in reality, $\Delta_1\alpha\int\left(\frac{d\alpha}{dt} - \cot\epsilon\frac{d\mu}{dt}\right)dt$, and this is of the form $\tan\delta\int f(t)dt$; so that $\cot\delta$ disappears.

† *Obs. de Poulkova*, t. i. See also my *Traité des Réductions Stellaires*, p. 79.

ascension, $\tan\delta$ or $\sec\delta$ in declination, are not included, so that:—

$$(6)\qquad \Delta A_\alpha = \frac{2}{\sin 2\delta} A_\alpha A_\delta$$

$$\Delta A_\delta = -\tfrac{1}{4}\sin 2\delta A_\alpha^2 - \frac{2}{\sin 2\delta}(A_\delta)^2.$$

4. *Some of the Terms of Second Order of the Nutation and of the Annual Aberration.*

Combining now all the terms of the second order given above, Δ_α, Δ_δ being the terms of the first order of the complete reduction to the apparent place, and $\Delta^2\alpha$, $\Delta^2\delta$ those of the second order, we have, first,

$$\Delta_\alpha = \Delta_1\alpha + A_\alpha$$

$$\Delta\delta = \Delta_1\delta + A_\delta.$$

Taking the sum of the formulæ (4′) (5) and (6) we obtain in right ascension

$$\Delta^2\alpha = \tan\delta\Delta_1\delta(\Delta_1\alpha + A_\alpha) + \frac{2}{\sin 2\delta}A_\delta(\Delta_1\alpha - A_\alpha) + F.$$

But

$$\frac{2}{\sin 2\delta} = \frac{\tan\delta}{\sin^2\delta}, \text{ and, for polar stars, } = \tan\delta + \tfrac{1}{2}\sin 2\delta,$$

and $\sin 2\delta$ being very small, we may neglect $\frac{1}{2}\sin 2\delta$, hence

$$\Delta^2\alpha = \tan\delta\Delta\alpha\Delta\delta + F$$

$$(7)\qquad \Delta^2\delta = -\tfrac{1}{2}\cot\delta(\Delta_1\alpha)^2 - \tfrac{1}{2}\sin 2\delta A_\alpha\Delta_1\alpha - \tfrac{1}{4}\sin 2\delta A_\alpha^2 - \frac{2}{\sin 2\delta}(A_\delta)^2;$$

also, putting

$$\tfrac{1}{2}\sin 2\delta = \cot\delta$$

$$\Delta^2\delta = -\tfrac{1}{2}\cot\delta(\Delta_1\alpha + A_\alpha)^2 - \tan\delta(A_\delta)^2$$

$$(7')\qquad = -\tfrac{1}{2}\cot\delta(\Delta\alpha)^2 - \frac{2}{\sin 2\delta}(A_\delta)^2,$$

this being the first form of Fabritius* with the additional term

$$-\frac{2}{\sin 2\delta}(A_\delta)^2.$$

If, on the contrary, we put $\frac{1}{4}\sin 2\delta$ instead of $\frac{1}{2}\cot\delta$, we have

$$(7'')\qquad \Delta^2\delta = -\tfrac{1}{4}\sin 2\delta(\Delta\alpha)^2 - \frac{2}{\sin 2\delta}(A_\delta)^2,$$

this differing only by the last term from the second form given

* *Obs. de Kiew,* t. i., and Oppolzer, *Traité de la Détermination des Orbites*, p. 264.

by Fabritius in consequence of our criticism.* We give the preference to this last form for two reasons: first, the calculation of sin 2δ is used in the two terms; second, sin 2δ is factor in two terms in (7), and cot δ only in one. Therefore we adopt for the terms of the second order of the reduction to the apparent place

$$\Delta^2\alpha = \tan\delta\Delta\alpha\Delta\delta + \mathrm{F}$$

$$\Delta^2\delta = -\tfrac{1}{4}\sin 2\delta(\Delta\alpha)^2 - \frac{2}{\sin 2\delta}(\mathrm{A}_\delta)^2,$$

differing from those of Fabritius by the last terms, which should not be neglected.

If we make use, for the reduction of close polar stars, of the very convenient forms of Fabritius, we are then obliged to add: in A R,

$$\mathrm{F} = -\cot.\epsilon\tan\delta\{\tfrac{1}{2}\cos\alpha(\Delta\mu)^2 + \sin\alpha\int\Delta\theta d\mu\}$$

$$= -\tan\delta\,\{\cos\alpha[0''.0023t^2 - 0''.0015\sin\Omega t] - 0.0063\sin\alpha\sin\Omega\};$$

and in δ:

$$-\frac{2}{\sin 2\delta}(\mathrm{A}_\delta)^2.$$

5. *Periodic terms of the systematic aberration.*

I have called attention to these terms in my *Traité des Réductions Stellaires* (1888). I will find these terms in right ascension and in declination, not taking account of other terms of the second order, included in the preceding formulæ, with the exception of very small terms (of the second order) depending on the longitude of the Sun and of the perigee.

The formulæ of the aberration are:

$$(1)\qquad \mathrm{K}\cos\delta^1\cos\alpha^1 = \cos\delta\cos\alpha + \frac{1}{v}\mathrm{V}_x$$

$$(2)\qquad \mathrm{K}\cos\delta^1\sin\alpha^1 = \cos\delta\sin\alpha + \frac{1}{v}\mathrm{V}_y$$

$$(3)\qquad \mathrm{K}\sin\delta^1 = \sin\delta + \frac{1}{v}\mathrm{V}_z;$$

from which we take

$$(4)\qquad \Delta\alpha = \frac{\sec\delta}{v}(\cos\alpha\mathrm{V}_y - \sin\alpha\mathrm{V}_x) - \frac{\sec^2\delta}{v^2}(\cos\alpha\mathrm{V}_y - \sin\alpha\mathrm{V}_x)(\sin\alpha\mathrm{V}_y + \cos\alpha\mathrm{V}_x).$$

From (1) and (2) we may deduce

$$(5)\qquad \mathrm{K}\cos\delta^1 = \cos\delta + \frac{\cos\delta}{v}(\sin\alpha\mathrm{V}_y + \cos\alpha\mathrm{V}_x) + \tfrac{1}{2}\frac{\sec\delta}{v^2}(\mathrm{V}_x{}^2 + \mathrm{V}_y{}^2),$$

* *Obs. de Kiew*, t. iii.

and from (3) and (5)

$$\Delta\delta = \frac{\cos\delta}{v}\left\{V_z - \sin\delta(\sin\alpha V_y + \cos\alpha V_x\right\} - \frac{1}{2}\frac{\tan\delta}{v^2}(V_x^2 + V_y^2),$$

if we make abstraction of the terms of second order, in which $\tan\delta$ is not included.

If we take only into account the annual and the systematic aberration, calling m_1 the mean motion of the Sun, σ_1 the systematic velocity, σ' its projection on the equator, A′, D′ the coordinates of the apex, s, c the sin and cos of the obliquity, $\odot$ the Sun's longitude, we have:

$$V_x = m_1 \sin\odot + \sigma' \cos A'$$
$$V_y = -m_1 c \cos\odot + \sigma' \sin A'$$
$$V_z = -m_1 s \cos\odot + \sigma' \tan D';$$

and therefore

$$(6)\quad \cos\alpha V_y - \sin\alpha V_x = -m_1(c\cos\alpha\cos\odot + \sin\alpha\sin\odot) + \sigma'\sin(A'-\alpha)$$

$$(7)\quad \sin\alpha V_y + \cos\alpha V_x = -m_1(c\sin\alpha\cos\odot - \cos\alpha\sin\odot) + \sigma'\cos(A'-\alpha)$$

$$V_x^2 + V_y^2 = m_1^2(\sin^2\odot + c^2\cos^2\odot) + \sigma'^2 - 2m_1\sigma'(c\sin A'\cos\odot - \cos A'\sin\odot);$$

or, neglecting the constant terms,

$$V_x^2 + V_y^2 = -\tfrac{1}{2}m_1^2 s^2 \cos 2\odot - 2m_1\sigma^1(c\sin A^1\cos\odot - \cos A^1\sin\odot).$$

Taking only into account in the formulæ (6) and (7) the periodical terms of the systematic aberration:

$$(\cos\alpha V_y - \sin\alpha V_x)(\sin\alpha V_y + \cos\alpha V_x)$$
$$= -m_1\sigma'\{c\cos(A'-2\alpha)\cos\odot - \sin(A'-2\alpha)\sin\odot\}.$$

The periodical terms of the systematic aberration will be therefore, if a be the annual constant of aberration, and a' the reduced constant of systematic aberration, viz., projected on the equator:

$$\Delta^2\alpha = -aa'\sec^2\delta\{c\cos(A'-2\alpha)\cos\odot - \sin(A'-2\alpha)\sin\odot\}$$
$$\Delta^2\delta = aa'\tan\delta(c\sin A'\cos\odot - \cos A'\sin\odot).$$

If $a^1 = a$, aa^1 (expressed in seconds of arc) $= 0''{\cdot}002$, the terms above may not be neglected, in the reduction of close polar stars.

These formulæ offer a very easy means of computing a', a means unknown until to-day.

When the constant of the systematic aberration is known, we may compute the terms arising from the combination of this aberration with the nutation. These are (making abstraction of the terms of first order, A'_α and A'_δ,

which are not periodical and cannot be used in the formulæ of reduction):

$$\delta A'_{\alpha} = \tan \delta A^{1}{}_{\alpha} \Delta_1 \delta - \frac{2}{\sin 2\delta} A'_{\delta} \Delta_1 \alpha$$

$$\delta A'_{\delta} = \tfrac{1}{2} \sin 2\delta A^{1}{}_{\alpha} \Delta_1 \alpha.$$

If the systematic velocity be of the same order as the velocity of the Earth, these terms will be of the same magnitude as the corresponding terms in the annual aberration.

Uccle: May 5.

On a Parallel-Plate Double-Image Micrometer. By J. H. Poynting.

(*Communicated by Sir R. S. Ball.*)

If a ray of light passes through a plate of glass with parallel faces it emerges parallel to its original direction, but with any other than normal incidence it is shifted through a distance proportional nearly to the tangent of the angle of incidence, up to quite considerable values of that angle.

I have already published an account of a use of this property in obtaining a fine adjustment for a cathetometer telescope. (*Phil. Trans.* vol. 182 (1891), A., p. 588.) A parallel plate movable round a horizontal axis is placed just in front of the object-glass. The telescope is brought nearly to the level of the point to be sighted, and the final adjustment is completed by tilting the plate until the point appears on the cross wire.

We have for some time used a similar device with a microscope on the Mason College Physical Laboratory for the measurement of small objects, placing the parallel plate between the stage and objective. It is very easy and very rapid in use. The plate might be placed, for the measurement of smaller objects, between the objective and eyepiece, but we have never required the sensitiveness which would thus be obtained.

I have lately applied the principle in the construction of a double-image micrometer for a telescope, and as the instrument, as far as I can test it, appears to be successful, it may be worthy of description.

A circular parallel plate of glass, rather more than 1 inch in diameter and about $\frac{1}{8}$ inch thick, being cut down the middle, one half is fixed in one semicircle of a ring, while the other is placed in the other semicircle, attached, however, to an axis passing through a bearing in the ring, so that the plate can be rotated, the axis being in the plane of the fixed plate and perpendicular to its edge at the middle point. The ring is

fixed in the tube of a 4-inch telescope of about 67 inches focal length, 16 inches in front of the focal plane, the division between the two plates being vertical. The axis of the movable plate passes out horizontally through the side of the tube, and a pointer is attached at right angles to it moving over a fixed straight scale, the pointer being nearly at the middle of the scale when the two plates are in one plane.

On looking at a star with the plates thus in one plane one image only is seen. But on moving the pointer the one plate is tilted and all the rays through it are shifted, so that two images appear, their separation being proportional nearly to the movement of the pointer along the scale. In the fixed position of the micrometer with the division between the plates vertical, it is possible only to measure vertical distances. For general use, of course, it should be possible to revolve it about the axis of the telescope. It was fixed merely for simplicity of construction in preparing it to test the method.

The separation of the images for a given angle of tilt might be calculated by the method given at the end of this note, knowing the exact thickness of the plate and its refractive index. But it appeared preferable to obtain the value per division of the scale by experiment. For this purpose the eyepiece of the telescope was removed and a fine scale of 500 divisions to the inch was fixed in the focal plane of the objective. Another telescope focussed for an infinite distance was then placed in front of the objective and the image of the fine scale was viewed by it. The movable plate was then tilted so that the lines of the fine scale in one image moved one place on, two places on, and so on, the positions of coincidence being easily determined. The tilts corresponded, of course, to displacements of the image, in the use of the micrometer, by successive 1-500ths of an inch. Within more than ten divisions on each side of the middle of the pointer scale the movements were proportional to the shifting of the fine scale, and the mean of a number of readings made twenty-one divisions of the pointer scale correspond exactly to eight divisions of the fine scale. The effective focal length of the objective might be taken as 67·16 inches, this being the distance from the near side of the flint glass to the focal plane. For exact work it would be necessary to calculate the position of the principal point for the system of lenses, but this would be quite needless refinement here. Hence

$$1 \text{ division of pointer scale} = \frac{8}{21} \times \frac{1}{500} \times \frac{1}{67\cdot16} \text{ radius, or } 2\cdot34 \text{ seconds.}$$

As ten divisions of the pointer scale occupy a length of 12·68 mm., and the scale is 67·5 mm. from the axis, ten divisions means an angle of tilt less than 11°, and up to this the error in taking the displacement as proportional to the movement of the pointer along the scale is not more than 1 in 600. I have found that with my telescope it is quite sufficient to move the pointer

by hand, though with a steady stand and good definition a screw motion would be useful.

I have tested the micrometer by measuring the distance between the components of *Castor* when one is vertically over the other, and by measuring a vertical diameter of *Saturn*, using a power of 100. I have no experience of micrometer work, and do not know the accuracy to be expected, but, considering the very inferior definition of my telescope, and the unsteadiness of the stand, the results obtained appear to be hopeful for the success of the method.

The following are the results, in each case, of course, giving double the actual angle.

DISTANCE BETWEEN TWO COMPONENTS OF CASTOR.

1892 *April* 22. *Readings of Pointer Scale.*

1st position with one component in one image on the other component in the other image.	2nd position with one component in one image on the other component in the other image.
34·2	28·6
33·1	28·1
33·1	28·1
33·1	27·7
32·9	28·5

Rejecting the first readings as made without experience, the mean difference is 4·95 divisions.

Hence angular separation of the components

$$\tfrac{1}{2} \times 4{\cdot}95 \times 2{\cdot}34 = 5''{\cdot}79.$$

1892 *May* 9. *Readings of Pointer Scale.*

1st Position.	2nd Position.	1st Position.	2nd Position.
27·4	22·0	27·3	22·1
27·0	22·0	27·3	22·6
26·9	22·0	27·7	22·0
27·0	22·0	27·0	22·5
27·4	22·5	27·0	22·4

The mean difference is 4·99 divisions.

Hence angular separation of the components is

$$\tfrac{1}{2} \times 4{\cdot}99 \times 2{\cdot}34 = 5''{\cdot}84.$$

In Denning's *Telescopic Work* (p. 304) the separation is given as 5″ 68.

VERTICAL DIAMETER OF SATURN.

1892 *April* 22. *Readings of Pointer Scale.*

1st position of movable image touching fixed image.	2nd position of movable image touching fixed image.
23·0	37·7
23·0	37·6
23·0	37·8

The mean difference is 14·7 divisions.

Hence vertical diameter is

$$\tfrac{1}{2} \times 14{\cdot}7 \times 2{\cdot}34 = 17''{\cdot}2.$$

I did not observe the angle the measured diameter made with the polar diameter, but from the westerly position of the planet I estimate it at over 30°. The polar diameter on this evening was

$$17''{\cdot}2,$$

so that the above is rather too small.

1892 *May* 9. *Readings of Pointer Scale.*

1st Position.	2nd Position.	1st Position.	2nd Position.
17·5	31·7	17·6	31·9
17·6	31·6	17·7	31·6
17·7	31·7		

The mean difference is 14·08 divisions.

Hence vertical diameter is

$$\tfrac{1}{2} \times 14{\cdot}08 \times 2{\cdot}34 = 16''{\cdot}5.$$

The diameter measured appeared to make about 20° with the polar diameter, which on this evening was

$$16''{\cdot}8.$$

Note on the calculated Value of the shifting of a Ray incident on a Parallel Plate.

Let the angle of incidence be ϕ, that of refraction ψ. Let t be the thickness of the plate, and μ its index of refraction. It is easily shown that the shift is

$$s = \frac{t \sin(\phi - \psi)}{\cos\psi}$$

$$= t \tan\phi \frac{\cos\phi \sin(\phi-\psi)}{\sin\phi \cos\psi}$$

$$= t \tan\phi \frac{(1-\sin^2\phi)^{\frac{1}{2}}}{\sin\phi} \left\{ \sin\phi - \frac{(1-\sin^2\phi)^{\frac{1}{2}} \sin\phi}{\mu\left(1 - \frac{\sin^2\phi}{\mu}\right)^{\frac{1}{2}}} \right\}$$

$$= t \tan\phi \left\{ (1-\sin^2\phi)^{\frac{1}{2}} - \frac{1-\sin^2\phi}{\mu}\left(1-\frac{\sin^2\phi}{\mu^2}\right)^{-\frac{1}{2}} \right\}$$

$$= t \tan\phi \left\{ 1 - \frac{\sin^2\phi}{2} - \frac{\sin^4\phi}{8} - \frac{\sin^6\phi}{16} \quad . \quad . \quad . \right.$$

$$\left. - \frac{1-\sin^2\phi}{\mu}\left(1 + \tfrac{1}{2}\frac{\sin^2\phi}{\mu^2} + \tfrac{3}{8}\frac{\sin^4\phi}{\mu^4} + \tfrac{5}{16}\frac{\sin^6\phi}{\mu^6} + \right)\right\}$$

$$= t \tan\phi \left\{ \frac{\mu-1}{\mu} - \sin^2\phi\left(\frac{1}{2} - \frac{1}{\mu} + \frac{1}{2\mu^3}\right) \right.$$

$$- \sin^4\phi\left(\frac{1}{8} - \frac{1}{2\mu^3} + \frac{3}{8\mu^5}\right)$$

$$- \sin^6\phi\left(\frac{1}{16} - \frac{3}{8\mu^5} + \frac{5}{16\mu^7}\right)$$

$$\left. - \text{\&c.} \right\}$$

Taking $\mu = \frac{4}{3}$ and ϕ successively 5°, 10°, and 20°, then approximately

$$s = \frac{t}{3} \tan 5^\circ \,(1 - \cdot 00042)$$

$$s = \frac{t}{3} \tan 10^\circ \,(1 - \cdot 00156)$$

$$s = \frac{t}{3} \tan 20^\circ \,(1 - \cdot 00529).$$

The Lunar Eclipse, 1892 *May* 11: *Observations made at Mr. Crossley's Observatory, Bermerside, Halifax.* By Edward Crossley, M.P., and Joseph Gledhill.

The weather here on the 11th was all that could be desired—a cloudless day and night. Owing, however, to the low position of the Moon (altitude about 18° when on the meridian) the naked-eye and other phenomena were not well seen before 10 o'clock. But as the Moon got higher the spectacle was very fine: the eclipsed portion was seen to be of a clear ruddy tinge, and the principal lunar seas, &c., were readily seen and identified with the help of an opera-glass. This beautiful colour disappeared about midnight, and gave place to a dull grey tinge.

While watching for the occultations of the stars given in the *Observatory* for May, an attempt was made to note the times when the general curve of the dark shadow reached some of the best-known craters.

The instrument used throughout the observations was the $9\frac{1}{3}$-inch Cooke refractor, power 66.

Before mid-eclipse :—

			G.M.T. h m s
Aristarchus,	1st edge	of crater	9 18 16
Kepler,	"	"	25 27
Copernicus,	"	"	32 36
"	2nd	"	33 30
Plato,	1st	"	33 0
"	middle	"	34 0
Archimedes,	1st edge	"	37 0
"	middle	"	38 2
"	2nd edge	"	38 30
Aristotle,	1st	"	43 7
Eudoxus,	"	"	43 45
Aristotle,	2nd	"	44 30
Eudoxus,	"	"	45 15
Linné,			46 30
Menelaus,			53 30
Bessel,			51 24
Tycho,	1st	"	10 8 38
"	2nd	"	12 23
Proclus,			8 15

After mid-eclipse :—

		G.M.T. h m s
Aristarchus,		11 49 22
Copernicus,	1st edge	53 22
"	middle of crater	54 27
"	2nd edge of crater	55 29
Proclus,		12 26 28

Occultations.

Careful watch was kept on the sky near the advancing limb of the Moon, but no stars could be seen until about 10 o'clock. Several very faint ones were seen as the time went on, but they could not be seen when close to the Moon's limb. The following observations were made: the earlier ones by Mr. Crossley at the telescope and a friend at the chronometer; after 11 o'clock I took charge of both instruments.

Time.	Phenomena.	Angle.	G.M.T. Observed Time.	Remarks.
h m		°	h m s	
9 45	D	142	...	No star seen near limb.
49	D	65		
10 16	D	112	10 15 26	
20	D	94	10 19 32	
26	R	355	...	Not seen until a little way from limb.
33	D	90	10 33 47	
43	D	103	10 40 51	Perhaps 1 sec. too late.
58	R	281	...	Faint star; not seen till away from limb.
11 0	D	57	...	Faint star; not seen till away from limb.
12	D	109	...	Faint star; not seen till away from limb.
31	R	327	11 28 34	
34	R	309	11 31 6	
42	R	332	11 39 35	
43	R	8	11 43 57	Very faint.
59	R	317	...	A bright star; lost owing to interruption.
12 31	R	306	12 28 15	Not seen double; examined it with 240.

The times of the occultation phenomena were taken to the nearest second. With regard to the times when the dark edge of the shadow touched a crater-wall, &c., they also were taken from the chronometer—i.e., when the shadow appeared just to touch a wall the chronometer time was recorded.

Bermerside, Halifax:
1892 *May* 13.

Occultations of Stars by the Eclipsed Moon, 1892 *May* 11, *and other Phenomena*, observed by the Rev. A. Freeman, M.A.

The stars are those of the list published in the *Observatory* of 1892 May. The telescope employed was my 6½-inch refractor, with an eyepiece having a power of 35 and a field of 1° 8′ in diameter. The time is dependent on comparisons of a solar chronometer with a trustworthy electric time-signal, May 4 and May 12, showing a daily gaining rate of only $0^s{\cdot}14$ in the interval.

B.D. −19°.	Magn.	Occ.	G.M.T. h m s	Remarks.
4091	8·3	D.	10 17 25·25	Sudden.
4095	8·9	D.	10 35 51·25	Sudden.
4087	9·7	R.	11 3 4·25	Late.*
4099	8·2	D.	11 14 18·25	Final.†
4091	8·3	R.	11 35 2·25	Sudden.
4095	8·9	R.	11 44 14·25	Late.‡
4097	9·4	R.	11 48 9·25	Late.*

Phenomena of the Shadow.

h m	
9 11·4	Moon has entered shadow (late).
9 17·4	Shadow bisects Aristarchus.
9 31·4	Shadow touches Copernicus ring on E.
9 32·9	Shadow touches Mersenius on E.
9 34·0	Shadow covers Mersenius.
9 34·8	Shadow touches Copernicus ring on W.
10 9·2	Shadow touches Tycho ellipse on E.
10 11·1	Shadow bisects Tycho.
10 12·5	Shadow touches Tycho ellipse on W.
11 20·9	Shadow touches Tycho on S.
11 22·4	Shadow bisects Tycho.
11 24·0	Shadow touches Tycho on N.
12 37·5	Moon has left shadow (late).

There was a certain amount of haze about throughout the eclipse, varying in density but without cloud. The haze became

* Star first seen 22″·3 off limb of ☽ (= half greater axis of Tycho).
† This double star hung on the limb for two or three seconds.
‡ Star first seen 8″·2 off limb of ☽ (= quarter least axis of Tycho).

so dense at the end of the eclipse as to entirely conceal the reappearance of 4099, which was unfortunate. At the time of the greatest eclipse I estimated that only one-twentieth of the diameter of the Moon was uncovered, giving a magnitude of eclipse 0·950, closely agreeing with the *Nautical Almanac* 0·953. The eclipsed Moon at greatest obscuration appeared to have a bluish-grey tinge near the border of the shadow, and this tint gradually changed and finally became of a warm orange-grey tinge at the region furthest from the uneclipsed part of the Moon. There was a singular appearance within the shadow of bright curved wedge-like parts, with their bases on the east and west ends of the shadow's boundary, and with their points on the Moon's limits quite 40° from the illuminated part. The eastern wedge was the brighter of the two, but their magnitudes were the same. The existence of these wedges was manifest to the unaided eye, and to it the colour of the shadow at greatest obscuration was dark copper, it having been a few minutes previously bright copper. Two or three lunar peaks were visible near the S.W. point of Moon's limb, the loftiest projection a little S. of S.W.; there was a solitary, rather smaller, projecting peak near the S.E. point of the Moon's limb. During the progress of the eclipse the penumbra gave a pale straw colour to the lunar surface covered by it. The position of the observatory is $3^{m}\ 0^{s}$ E., and 51° 20′ N. approximately.

Murston Rectory, Sittingbourne:
1892 *May* 23.

Occultation of 73 *Piscium by Jupiter,* 1892 *May* 23, *observed at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer-Royal.*)

Notice was called to this phenomenon by Mr. Marth in the April number of the *Monthly Notices*, and as the morning was fine, an attempt was made to observe it with the 10-inch guiding telescope of the photographic equatorial. Owing to the low altitude of *Jupiter*, its limb was boiling violently, and accurate observation was only possible at occasional brief intervals of good definition.

The following notes describe what was seen at these moments:—

Phenomenon Observed.	Observer.	Sidereal Time. h m s	Mean Time. d h m s
Disappearance.			
Star almost in contact with limb	A. C.	19 25 49	23 15 17 4
Star apparently bisected	„	19 27 20	18 35
No trace seen of star	„	19 32 44	23 58
Reappearance.			
Star suspected for a moment	„	19 41 11	32 24
Star certainly reappeared	„	19 46 7	37 19

It is probable that the time marked "Star suspected" is approximately correct for the reappearance, but the boiling of the limb made it impossible to verify it with certainty for some minutes more.

Mr. Marth's paper gave the Greenwich mean time of mid-occultation as $15^{h}\ 36^{m}{\cdot}6$, and the duration as $17^{m}{\cdot}2$. So far as the above rough observations are to be trusted, they seem to show that the Greenwich mean time of mid-occultation was $15^{h}\ 25^{m}{\cdot}6$, and the duration $12^{m}{\cdot}8$, or thereabouts.

The Greenwich observations of *Jupiter* at the end of 1891 gave as the error of Tabular R.A. $-0^{s}{\cdot}18$, the error of Tabular N.P D. being about $-0''{\cdot}1$.

The apparent place of the star according to the Greenwich Ten-Year Catalogue, 1880, was R.A. $0^{h}\ 59^{m}\ 16^{s}{\cdot}297$; N.P.D. $84^{\circ}\ 55'\ 23''{\cdot}15$. The Glasgow Catalogue gives the R.A. $0^{s}{\cdot}12$ greater, the N.P.D. $1''{\cdot}74$ smaller.

The initials are those of Mr. Crommelin.

Erratum in Monthly Notices, May 1892, *p.* 517.

			h m s		s
B.D. -19° 4091	Dis.:	for Sidereal Time	13 37 8·0	read	8·2
		for Mean Time	10 16 31·1	read	31·3

Observations of Swift's Comet (a 1892) made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the East, or Sheepshanks, equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

The observations are corrected for refraction, but not for parallax.

Greenwich Mean Solar Time.	Observer.	☄−✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	☄−✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	App. R.A. of ☄.	App. N.P.D. of ☄.	Comp. Star.
d h m s		m s	s		′ ″	″			h m s	° ′ ″	
May 14 12 25 15	A. C.	+1 40·53	−0·03	9·6027	− 3 16·8	−0·2	0·8358	5	23 10 46·81	60 45 53·9	*a*
14 12 25 15	,,	−1 16·64	+0·03	9·6027	+ 2 41·4	+0·2	0·8358	5	23 10 45·98	60 45 50·7	*b*
14 13 24 10	L.	+1 48·08	−0·01	9·6244	− 4 45·5	+0·3	0·7905	3	23 10 54·38	60 44 25·7	*a*
14 13 24 10	,,	−1 9·22	+0·00	9·6244	+ 1 9·9	−0·1	0·7905	3	23 10 53·37	60 44 18·9	*b*
15 12 48 51	B.	+1 48·43	−0·01	9·6180	− 1 0·2	0·0	0·8163	2	23 13 30·58	60 12 3·5	*c*
15 12 45 38	,,	+0 51·23	+0·02	9·6165	+ 4 15·5	+0·2	0·8188	3	23 13 29·19	60 12 18·6	*d*
15 12 48 51	,,	−2 1·85	+0·01	9·6180	+ 1 29·8	+0·1	0·8163	2	23 13 29·88	60 12 10·0	*e*
23 12 44 14	A. C.	+2 7·30	+0·04	9·6397	+12 27·8	+0·3	0·7974	2	23 33 54·93	56 9 38·9	*f*
23 12 44 14	,,	+0 2·95	+0·06	9·6397	+17 30·4	+0·5	0·7974	2	...	...	*g*
28 12 20 6	,,	+1 32·70	−0·04	9·6425	−14 1·6	−0·2	0·8048	3	23 45 47·35	53 56 34·9	*h*
28 12 25 0	,,	+0 29·47	−0·00	9·6467	− 1 33·0	0·0	0·8000	5	23 45 47·07	53 56 36·2	*i*
28 12 30 19	,,	−1 43·43	+0·04	9·6491	+17 36·8	+0·2	0·7950	3	...	...	*k*

Comparison Stars.

	Star's Name.	Mean R.A., 1892·0. h m s	Mean N.P.D. 1892·0. ° ′ ″	Authority.
a	W.B. (2) XXIII. 131 and 132	23 9 6·77	60 48 58·3	Weisse's Bessel, vol. ii.
b	W.B. (2) XXIII. 206 and 207	23 12 3·06	60 42 56·7	„ „
c	W.B. (2) XXIII. 194	23 11 42·61	60 12 51·2	„ „
d	W.B. (2) XXIII. 217	23 12 38·39	60 7 50·4	Second Armagh Catalogue, 1875.
e	63 Pegasi	23 15 32·19	60 10 27·8	Greenwich Seven-Year Catalogue, 1864.
f	B.D. + 33° 4744	23 31 47·96	55 56 58·9	Bonn Observations, vol. vi.
g	B.D. + 33° 4749	23 33 52·5	55 52	„ „ vol. iv.
h	W.B. (2) XXIII. 907	23 44 15·00	54 10 25·5	Greenwich Ten-Year Catalogue, 1880.
i	W.B. (2) XXIII. 920	23 45 17·92	53 57 58·0	Weisse's Bessel, vol. ii.
k	B.D. + 36° 5126	23 47 31	53 39	Bonn Observations, vol. iv.

Notes.

Stars *a*, *b*, and *f* are all double stars, the components being nearly equal. In each case the mean of the places of the components has been used, as with the low power employed the duplicity was not observed.

On May 23 the comet was noted as very large and bright, with a bifurcated tail.

The places of the comet continue to agree closely with Berberich's Ephemeris.

The initials L., A.C., B., are those of Mr. Lewis, Mr. Crommelin, and Mr. Bryant respectively.

Observations of Comet 1892 a (Swift), made at the Royal Observatory, Cape of Good Hope.

(Communicated by D. Gill, LL.D., F.R.S., H.M. Astronomer.)

1892.		Cape Mean Time.	Comet−✱ Δα	Comet−✱ Δδ	No. of Comp. R.A.	No. of Comp. N.P.D.	Observer.	Comet App. R.A.	Log p×Δ	Comet App. Decl.	Log p×Δ	Red. to App. Place.		Comp. Star No.
		h m s	m s	′ ″				h m s		° ′ ″		s	″	
Mar.	8	16 58 31·8	−1 16·42	−1 54·8	6	6	F.	19 6 27·78	9·960	−30 2 54·4	0·213	−0·87	− 5·2	1
	9	15 31 24·5	...	−3 26·6	...	2	F.	...	...	−29 16 33·3	0·453	−0·82	− 5·5	2
		15 41 22·0	−1 34·78	...	8	0	F.	19 11 3·31	9·704	...	...	−0·82	− 5·5	2
	10	15 50 13·3	+1 3·35	+0 20·5	8	8	F.	19 15 53·53	9·693	−28 25 24·2	0·430	−0·83	− 5·7	3
	11	15 42 1·5	−2 41·44	+0 14·5	8	8	F.	19 20 37·60	9·698	−27 34 2·3	0·464	−0·83	− 6·0	4
	16	15 55 44·4	+2 49·93	+5 21·8	10	8	F.	19 43 51·53	9·672	−22 59 13·5	0·502	−0·74	− 7·3	5
	19	14 54 32·7	...	+3 4·9	...	2	F.	...	...	−20 6 9·0	0·609	−0·70	− 8·1	6
		15 3 58·0	+2 54·25	...	2	0	F.	19 56 56·74	9·703	...	...	−0·70	− 8·1	6
	20	15 32 48·9	−0 23·36	+2 34·1	20	10	F.	20 1 34·52	9·682	−19 4 28·2	0·574	−0·71	− 8·4	7
	21	15 56 2·1	−1 47·96	−2 39·8	16	12	F.	...	9·661	...	0·560	−0·71	− 8·7	8
	23	15 46 25·6	−1 35·87	−1 56·6	12	12	F.	20 14 30·87	9·665	−16 0 9·9	0·588	−0·69	− 9·1	9
	26	16 3 0·6	...	−2 24·8	...	8	F.	...	...	−12 51 31·7	0·602	−0·66	− 9·8	10
		16 15 58·8	−1 35·78	...	12	0	F.	20 27 7·04	9·629	...	...	−0·66	− 9·8	10
	29	16 3 52·0	...	−0 56·0	...	10	F.	...	...	...	0·628	−0·63	−10·5	11
		16 31 48·7	+0 24·18	...	6	0	F.	...	9·604	...	...	−0·63	−10·5	11
	30	16 2 22·1	...	−1 22·0	...	4	F.	...	...	...	0·637	−0·63	−10·6	12
Apr.	1	16 16 55·3	+1 23·73	−3 5·9	12	12	F.	20 51 6·39	9·620	− 6 30 2·9	0·647	−0·61	−11·1	13
	3	16 5 21·9	+0 47·77	−3 46·9	12	12	F.	20 58 47·16	9·631	− 4 24 1·6	0·665	−0·61	−11·4	14

The observations are corrected for refraction.

Assumed Mean Places of Comparison Stars.

Comp. Star No.	R.A. 1892·0. h m s	Declination. 1892·0. ° ′ ″	Authority.
1	19 7 45·07	−30 0 54·4	Stone 10436.
2	19 12 38·91	−29 13 1·2	C.Z. XIX.[h] 504.
3	19 14 51·01	−28 25 39·0	C.Z. XIX.[h] 599 and comparison with C.Z. XIX.[h] 480.
4	19 23 19·87	−27 34 10·8	A.G.C. 26690.
5	19 41 2·34	−23 4 28·0	A.G.C. 27096.
6	19 54 3·19	−20 9 5·8	Cincinnati Z. 3321.
7	20 1 58·59	−19 6 53·9	Cincinnati Z. 3341.
8	20 7 47	−18 0	B.D. −18°, 5624.
9	20 16 7·43	−15 58 4·2	Yarnall 9046.
10	20 28 43·48	−12 48 57·1	Santini 1868.
11	20 38 55	− 9 39	B D. −9°, 5563.
12	20 44 34	− 8 36	B.D. −8°, 5490.
13	20 49 43·27	− 6 26 45·9	Munich Z. 4043.
14	20 58 0·00	− 4 20 3·3	Schj. 8465.

Notes.

March 9.—The comet shows a sharp nucleus, equal to a star of 9½ magnitude; the head is very bright and is visible to the naked eye as a hazy star of the fourth magnitude.

March 10.—Nucleus admits of very accurate observation.

March 19.—Thick fog prevented further observation.

March 21.—Well-defined nucleus, equal to star 9½ magnitude.

March 23.—Very bad definition; strong wind.

March 26.—A short faint tail visible in the finder.

March 30.—Fogged up completely before any right ascension could be secured.

April 1.—Nucleus sharp and bright, equal to a star 9 magnitude. Faint straight tail about 4° long.

April 2.—Nucleus not well defined; stars very unsteady.

All the observations have been made by Mr. W. H. Finlay.

Observations of Wolf's Periodic Comet, made at the Cambridge Observatory with the Northumberland Equatoreal and Square Bar Micrometer. By A. Graham, M.A., Chief Assistant.

(Communicated by the Secretaries.)

1891.	Greenwich M.T.	R.A. ☄	Decl. ☄	No. of Comp.	Mean Places of Comparison Stars. R.A. 1891·0.	Decl. 1891·0.	Authority.
		h m s	° ′ ″		h m s	° ′ ″	
Aug.	15·46266	2 51 54·72	27 44 11·3	5	2 49 24·23	27 48 53·7	4 Meridian Observations, Cambridge.
	18·48913	2 59 45·09	27 23 39·9	5	2 59 5·85	27 26 41·7	3 " " "
	28·46021	3 24 27·97	25 44 33·0	5	3 24 45·94	25 47 9·2	4 " " "
	28·46021	3 24 28·28	25 44 34·0	5	3 26 0·96	25 50 6·6	1 " " "
	29·43224	3 26 45·27	25 32 24·2	5	3 30 37·32	25 38 20·9	4 " " "
Sept.	1·40023	3 33 38·76	24 51 46·3	10	3 34 15·63	24 58 35·5	2 " " "
	2·42124	3 35 58·67	24 36 35·1	6	3 38 39·42	24 29 47·7	3 " " "
	8·40088	3 48 57·99	22 57 34·4	10	3 50 36·04	22 51 29·6	3 " " "
	9·45960	3 51 8·85	22 38 8·3	5	3 52 42·04	22 40 38·8	3 " " "
	10·41493	3 53 4·99	22 20 6·9	5	3 50 25·59	22 9 48·5	3 " " "
	11·42903	3 55 7·53	22 0 22·1	5	3 58 15·00	21 47 0·4	A[1] Tauri, Nautical Almanac.
	12·42207	3 57 3·85	21 40 29·6	10	3 58 15·00	21 47 0·4	" " "
	12·42207	3 57 3·73	21 40 30·3	10	3 58 53·04	21 42 50·9	A[2] Tauri, Greenwich Catalogue, 1880.
	14·43044	4 0 54·53	20 58 52·5	10	4 0 44·19	20 58 6·9	2 Meridian Observations, Cambridge.
	14·43044	4 0 54·69	20 58 51·0	10	4 1 19·04	20 58 14·0	4 " " "
	28·41396	4 23 20·21	15 14 2·2	10	4 20 7·98	15 22 14·4	71 Tauri, Greenwich Catalogue, 1872.
	28·41396	4 23 20·12	15 13 59·9	10	4 23 55·60	15 23 56·8	80 Tauri, Greenwich Catalogue, 1880.
Oct.	3·42147	4 29 19·01	12 49 30·4	10	4 27 39·46	13 1 18·4	3 Meridian Observations, Cambridge.
	3·42147	4 29 19·40	12 49 27·0	10	4 30 19·02	12 53 54·0	(*a*) " " "

	9·42594	4 34 56 37	9 44 41·6	1	4 33 44·48	9 40 0·3	3	”	”	”
	12·44611	4 37 7·39	8 8 14·2	5	4 35 17·59	8 4 7·3	3	”	”	”
	12·44611	4 37 7·20	8 8 15·9	5	4 40 41·34	8 7 12·8	3	”	”	”
	28·46773	4 41 33·09	− 0 32 51·8	10	4 42 42·07	− 0 35 5·2	3	”	”	”
	28·46773	4 41 33·16	− 0 32 53·1	10	4 43 26·14	− 0 34 9·1	3	”	”	”
	30·45186	4 41 18·74	− 1 35 6·7	11	4 39 7·66	− 1 38 10·6	3	”	”	”
	30·45186	4 41 18·65	− 1 35 8·5	11	4 43 7·04	− 1 32 58·3	2	”	”	”
Nov.	2·46056	4 40 39 92	− 3 6 55·7	4 (b)	4 40 22·01	− 3 6 32·7	3	”	”	”
Dec.	2·47738	4 23 38·52	−13 32 29·7	5	4 20 57·47	−13 31 48·6	3	”	”	”
	2·47738	4 23 38 63	−13 32 29·4	5	4 25 25·29	−13 30 23·1	3	”	”	”
	4·43092	4 22 27·42	−13 51 2·5	5	4 23 56·73	−13 54 6·5	3	”	”	”
	4·43092	4 22 27·37	−13 51 2·3	5	4 26 23·93	−13 52 41·2	3	”	”	”

The corrections for aberration and parallax are applied.

(*a*) This star is very faint. The right ascension given here depends on one meridian observation, the declination on three.
(*b*) Caught only occasional glimpses of the comet; seldom long enough for a complete observation.

Places of Nova Aurigæ, obtained with the Cambridge Transit-Circle, reduced to Mean Equinox, 1892·0.

1892.	R.A. 1892·0. h m s	Decl. 1892·0. ° ′ ″	1892.	R.A. 1892·0. h m s	Decl. 1892·0. ° ′ ″
Feb. 5	5 25 3·439	30 21 49·38	Feb. 16	5 25 3·392	30 21 48·64
11	·297	50·64	18	·450	49·47
12	·349	48·75	22	·289	49·40
13	·374	48·64	25	·414	49·58

The Observatory, Cambridge:
1892 *June* 2.

Sextant Observations of Swift's Comet taken on board the ship "Earnock" from Bluff Harbour, N.Z., to London.

By George F. Parson, Master of the ship "Earnock."

1892.	Approx. time Ship.	Latitude.	Longitude.	G.M.T.		Distance from Mars.	Distance from Vega.	Distance from Altair.	
		° ′	° ′		h m s	° ′	° ′	° ′	
Apr. 8	4 A.M.	29 20 S.	28 20 W.						A small comet first seen in Eastern sky, but no observations could be taken until April 26.
26	4 A.M.	3 6 N.	31 20 W.	Apr. 25	18 10 14	53 20			
					18 13 24		53 9		
					18 16 9			37 24	
28	3.30 A.M.	7 23 N.	34 20 W.	27	17 36 00	54 34			
					17 39 20		53 15		
					17 41 40			39 4	
May 2	3.30 A.M.	18 38 N.	39 50 W.	May 1	17 57 00	57 16			Very faint, and frequently obscured by light clouds.
					18 8 30		54 7		
					18 12 20			42 39	

Only faintly seen after this, owing to cloudy weather and early daylight.

Note on Damoiseau's "Tables Ecliptiques des Satellites de Jupiter." By A. M. W. Downing, M.A.

An examination of the fundamental numbers for the formation of the arguments of the inequalities, given by Damoiseau, pp. iii–viii of the Introduction to his Tables, has recently been made here, for the purpose of verifying (and, if necessary, carrying on) Adams' corrections to Damoiseau's values of the arguments, given on p. 17 of the Appendix to the *Nautical Almanac*, 1881. As it appears more convenient to have the corrected numbers than to apply corrections to the arguments formed from the erroneous numbers, it may be worth while putting on record the result of the examination of Damoiseau's work. It should be noted that the object of the corrections tabulated below is to make the arguments consistent with the data given at the top of p. iii of the Introduction.

First Satellite.

Argument.	*For.* s °		*Read.* s °	
$u_{I} - u_{II}$		$+ i$ 180°·7279427		$+ i$ 180°·7279424
$u_{I} - \varpi_{III}$	1 18·9465	$+ i$ 0·1344456	1 18·9459	$+ i$ 0·1344372
$u_{I} - \varpi_{IV}$		$+ i$ 0·1436792		$+ i$ 0·1436793
$u_{I} - 2u_{II} + \varpi_{III}$		$+ i$ 1·3214486		$+ i$ 1·3214475
$u_{I} - 2u_{II} + \varpi_{IV}$		$+ i$ 1·3122065		$+ i$ 1·3122054

Second Satellite.

Argument.	*For.* s °		*Read.* s °	
$U - \varpi'$		$+ i$ 3°·5029156		$+ i$ 3°·5029157
$U - u_{0}$		$+ i$ 3·2076333		$+ i$ 3·2076334
$u_{II} - u_{III}$	11 27·7519	$+ i$ 181·4617960	10 27·7519	$+ i$ 181·4617964
$u_{II} - \varpi_{III}$		$+ i$ 0·2699661		$+ i$ 0·2699663
$u_{II} - \varpi_{IV}$		$+ i$ 0·2885252		$+ i$ 0·2885256
$u_{I} - 2u_{II} + \varpi_{III}$		$+ i$ 2·6536288		$+ i$ 2·6536267
$u_{I} - 2u_{II} + \varpi_{IV}$		$+ i$ 2·6350694		$+ i$ 2·6350674
$u_{II} - \Pi$		$+ i$ 0·2953146		$+ i$ 0·2953149
$u_{II} - \Lambda_{II}$	8 21·8069	$+ i$ 0·4128461	8 21·8269	$+ i$ 0·4128463
$u_{II} - \Lambda_{III}$		$+ i$ 0·3201667		$+ i$ 0·3201668
$u_{II} - \Lambda_{IV}$		$+ i$ 0·3020441		$+ i$ 0·3020443

Third Satellite.

Argument.	*For.* s °		*Read.* s °	
$u_{II} - u_{III}$		$+ i$ 5°·8950578		$+ i$ 5°·8950600
$u_{III} - \varpi_{III}$	1 19·3500	$+ i$ 0·5443534	1 19·3502	$+ i$ 0·5443535
$u_{I} - 2u_{II} + \varpi_{III}$		$+ i$ 5·3507118		$+ i$ 5·3507070
$u_{I} - 2u_{II} + \varpi_{IV}$		$+ i$ 5·3132886		$+ i$ 5·3132845
$u_{III} - \Pi$		$+ i$ 0·5954489		$+ i$ 0·5954659
$u_{III} - \Lambda_{III}$	6 10·9058		6 10·9050	
$u_{III} - \Lambda_{II}$		$+ i$ 0·8324332		$+ i$ 0·8324532

FOURTH SATELLITE.

Argument.	*For.*		*Read.*	
	s °	°	s °	°
$U-\varpi'$	0 3·4178 + i	16·5123047	0 3·4181 + i	16·5123037
$U-u_0$	9 6·1550 + i	15·1203809	9 8·1553 + i	15·1203800
$u_{iii}-u_{iv}$	2 24·9629 + i	121·6066164	2 24·9726 + i	121·6066143
$u_{ii}-u_{iv}$	3 16·2853 + i	256·9946780	3 16·3121 + i	256·9946770
$u_{iv}-\varpi_{iv}$	6 3·4433 + i	1·3600749	6 3·4506 + i	1·3600734
$u_{iv}-\varpi_{iii}$	1 18·9271 + i	1·2726106	1 18·9343 + i	1·2725873
$u_{iv}-\Pi$	1 20·5205 + i	1·3921007	1 20·5277 + i	1·3920776
$u_{iv}-\Lambda_{iv}$	+ i	1·4238223	+ i	1·4237991
$u_{iv}-\Lambda_{iii}$	6 10·4045 + i	1·5092494	6 10·4118 + i	1·5092261
$u_{iv}-\Lambda_{ii}$	8 21·9415 + i	1·9461073	8 21·9488 + i	1·9461056

The greater number of these corrections are included in Adams' list mentioned above, and have therefore been applied in forming the times of eclipses given in the *Nautical Almanac* since 1881.

I suppose it is generally known that both the coefficient and argument of the inequality depending on the Great Inequality of *Jupiter* and *Saturn* (included in Damoiseau's Table III for the Second, Third, and Fourth Satellites) are erroneous. According to Souillart, the value of the argument is $5\bar{u}-2u_0-16° 633$; and the coefficients are $0^s{\cdot}711$, $2^s{\cdot}110$, and $11^s{\cdot}644$ for the Second, Third, and Fourth Satellites respectively. In the continuation of Adams' Tables, used in the *Nautical Almanac* for 1891 and subsequent years, Adams appears to have adopted nearly identical expressions to those found by Souillart for these inequalities.

Nautical Almanac Office:
1892 *June* 9.

Data for computing the Positions of the Satellites of Jupiter, 1892. By A. Marth.

The following data for computing the positions of the satellites during the present apparition of *Jupiter* correspond to the data for the preceding apparition on pages 518–523 of Vol. 51 of the *Monthly Notices*. The motions of the longitude and of arguments and the inequalities corresponding to the arguments are to be found there on pages 524–539.

First Satellite.

Greenwich Noon.	Longitude. $l_1-\odot$	$\mathfrak{S}_1$	Arguments. α_1	β_1	γ_1	δ_1	ϵ_1
1892. May 21	227·7103	+·0081	·1411	·035	·882	·057	·259
31	102·5999	80	·8141	·454	·530	·709	·284
June 10	337·4894	80	·4871	·872	·179	·362	·319
20	212·3790	79	·1601	·290	·827	·014	·333
30	87·2686	79	·8332	·708	·475	·666	·358
July 10	322·1581	+·0078	·5062	·127	·124	·319	·383
20	197·0477	78	·1792	·545	·772	·971	·407
30	71·9372	78	·8522	·963	·420	·623	·432
Aug. 9	306 8268	77	·5252	·381	·0 8	·275	·457
19	181·7164	77	·1982	·800	·717	·928	·481
29	56·6059	76	·8712	·218	·365	·580	·506
Sept. 8	291·4955	+·0076	·5442	·636	·013	·232	·531
18	166·3850	75	·2173	·054	·662	·884	·555
28	41·2746	75	·8903	·473	·310	·537	·580
Oct. 8	276·1642	74	·5633	·891	·958	·189	·605
18	151 0537	74	·2363	·309	·607	·841	·630
28	25·9433	74	·9093	·727	·255	·494	·654
Nov. 7	260·8328	+·0073	·5823	·146	·903	·146	·679
17	135·7224	73	·2553	·564	·552	·798	·704
27	10·6120	72	·9284	·982	·200	·450	·728
Dec. 7	245·5015	72	·6014	·400	·848	·103	·753
17	120·3911	71	·2744	·819	·497	·755	·778
27	355·2806	71	·9474	·237	·145	·407	·802
1893. Jan. 6	230·1702	+·0070	·6204	·655	·793	·059	·827
16	105·0598	70	·2934	·073	·442	·712	·852
26	339·9493	69	.9664	·492	·090	·364	·876
Feb. 5	214·8389	69	·6394	·910	·738	·016	·901
15	89·7284	68	·3125	·328	·387	·668	·926
25	324·6180	68	·9855	·746	·035	·321	·951
Mar. 7	199·5076	+·0068	·6585	·165	·683	·973	·975

	Inclination. γ_1	Node. $\odot-\Upsilon_1$		Inclination. γ_1	Node. $\odot-\Upsilon_1$
1892 May 11	0°·0083	113°·0	1892 Oct. 8	0°·0084	117°·0
June 10	83	113·7	Nov. 7	84	118·0
July 10	83	114·5	Dec. 7	85	119·0
Aug. 9	84	115·3	1893 Jan. 6	85	120·0
Sept. 8	84	116·1	Feb. 5	86	121·1
Oct. 8	84	117·0	Mar. 7	86	122·3

Greenwich Noon.	First Satellite. Arguments. ζ_1	η_1	θ_1	Second Satellite. Longitude. $l_2-\Omega$	S_2	Arguments. α_2	β_2
1892.				°	°		
May 21	·163	·584	·418	22·3110	+·0048	·07055	·035
31	·185	·605	·438	316·0583	46	·90706	·454
June 10	·207	·625	·459	249·8055	45	·74357	·872
20	·228	·646	·479	183·5528	43	·58007	·290
30	·250	·667	·500	117·3001	41	·41658	·708
July 10	·272	·688	·521	51·0473	+·0040	·25309	·127
20	·294	·708	·541	344·7946	38	·08959	·545
30	·315	·729	·562	278·5418	36	·92610	·963
Aug. 9	·337	·750	·582	212·2891	35	·76260	·381
19	·359	·771	·603	146·0363	34	·59911	·800
29	·381	·791	·624	79·7836	32	·43562	·218
Sept. 8	·402	·812	·644	13·5308	+·0030	·27212	·636
18	·424	·833	·665	307·2781	28	·10863	·054
28	·446	·854	·685	241·0254	26	·94514	·473
Oct. 8	·468	·874	·706	174·7726	25	·78164	·891
18	·489	·895	·727	108·5199	23	·61815	·309
28	·511	·916	·747	42·2671	21	·45466	·727
Nov. 7	·533	·937	·768	336·0144	+·0020	·29116	·146
17	·555	·957	·788	269·7616	18	·12767	·564
27	·576	·978	·809	203·5089	16	·96418	·982
Dec. 7	·598	·999	·829	137·2562	15	·80068	·400
17	·620	·020	·850	71·0034	13	·63719	·819
27	·642	·040	·871	4·7507	11	·47369	·237
1893. Jan. 6	·663	·061	·891	298·4979	+·0010	·31020	·655
16	·685	·082	·912	232·2452	08	·14671	·073
26	·707	·102	·932	165·9924	07	·98321	·492
Feb. 5	·729	·123	·953	99·7397	05	·81972	·910
15	·750	·144	·974	33·4869	03	·65623	·328
25	·772	·165	·994	327·2342	02	·49273	·746
Mar. 7	·794	·185	·015	260·9815	·0000	·32924	·165

	Inclination. γ_2	Node. $\Omega-\Gamma_2$	
1892.	°	°	
May 11	0·4904	129·16	
			95
June 10	·4902	130·11	
			96
July 10	·4899	131·07	
			95
Aug. 9	·4897	132·02	
			96
Sept. 8	·4895	132·98	
			96
Oct. 8	0·4892	133·94	

Second Satellite.

Greenwich Noon. 1892.	Arguments.								
	γ_2	δ_2	ϵ_2	ζ_2	η_2	θ_2	ι_2	κ_2	λ_2
May 21	·907	·487	·653	·163	·084	·918	·759	·654	·488
31	·722	·302	·469	·185	·105	·938	·784	·512	·345
June 10	·537	·118	·285	·207	·125	·959	·809	·369	·202
20	·352	·934	·101	·228	·146	·979	·833	·226	·059
30	·166	·750	·917	·250	·167	·000	·858	·083	·917
July 10	·981	·565	·733	·272	·188	·021	·883	·941	·774
20	·796	·381	·548	·294	·208	·041	·907	·798	·631
30	·611	·197	·364	·315	·229	·062	·932	·655	·488
Aug. 9	·425	·013	·180	·337	·250	·082	·957	·512	·345
19	·240	·828	·996	·359	·271	·103	·981	·370	·202
29	·055	·644	·812	·381	·291	·124	·006	·227	·059
Sept. 8	·870	·460	·628	·402	·312	·144	·031	·084	·916
18	·684	·276	·444	·424	·333	·165	·055	·941	·773
28	·499	·092	·260	·446	·354	·185	·080	·799	·630
Oct. 8	·314	·907	·076	·468	·374	·206	·105	·656	·488
18	·129	·723	·892	·489	·395	·227	·130	·513	·345
28	·944	·539	·708	·511	·416	·247	·154	·370	·202
Nov. 7	·758	·355	·523	·533	·437	·268	·179	·228	·059
17	·573	·170	·339	·555	·457	·288	·204	·085	·916
27	·388	·986	·155	·576	·478	·309	·228	·942	·773
Dec. 7	·203	·802	·971	·598	·499	·329	·253	·799	·630
17	·017	·618	·787	·620	·520	·350	·278	·657	·487
27	·832	·433	·603	·642	·540	·371	·302	·514	·344
1893. Jan. 6	·647	·249	·419	·663	·561	·391	·327	·371	·201
16	·462	·065	·235	·685	·582	·412	·352	·228	·059
26	·276	·881	·051	·707	·602	·432	·376	·086	·916
Feb. 5	·091	·696	·867	·729	·623	·453	·401	·943	·773
15	·906	·512	·683	·750	·644	·474	·426	·800	·630
25	·721	·328	·498	·772	·665	·494	·451	·657	·487
Mar. 7	·535	·144	·314	·794	·685	·515	·475	·515	·344

	Inclination. γ_2	Node. $\Theta - \Gamma_2$	
1892 Oct. 8	0°·4892	133°·94	
			96
Nov. 7	·4890	134·90	
			96
Dec. 7	·4887	135·86	
			97
1893 Jan. 6	·4885	136·83	
			96
Feb. 5	·4882	137·79	
			97
Mar. 7	0·4880	138·76	

Third Satellite.

Greenwich Noon.		Longitude. l_3-O	S_3	Arguments. α_3	β_3	γ_3	δ_3	ϵ_3
1892.		°	°					
May	21	189·6114	+·0039	·9513	·1177	·0353	·328	·619
	31	332·7875	37	·3489	·5154	·4535	·127	·058
June	10	115·9636	35	·7464	·9130	·8718	·925	·497
	20	259·1397	33	·1439	·3107	·2900	·724	·936
	30	42·3158	31	·5414	·7083	·7083	·523	·375
July	10	185·4919	+·0029	·9389	·1060	·1265	·321	·814
	20	328·6680	27	·3364	·5036	·5448	·120	·253
	30	111·8441	25	·7339	·9013	·9630	·918	·692
Aug.	9	255·0202	23	·1314	·2990	·3813	·717	·131
	19	38·1963	21	·5289	·6996	·7996	·515	·570
	29	181·3724	19	·9265	·0943	·2178	·314	·009
Sept.	8	324·5485	+·0017	·3240	·4919	·6361	·112	·448
	18	107·7246	15	·7215	·8896	·0543	·911	·887
	28	250·9007	13	·1190	·2872	·4726	·709	·326
Oct.	8	34·0768	11	·5165	·6849	·8908	·507	·765
	18	177·2529	09	·9140	·0826	·3091	·306	·204
	28	320·4291	07	·3115	·4802	·7273	·105	·643
Nov.	7	103·6052	+·0005	·7090	·8779	·1456	·903	·082
	17	246·7813	+·0003	·1065	·2755	·5638	·702	·521
	27	29·9574	+·0001	·5041	·6732	·9821	·500	·960
Dec.	7	173·1335	−·0001	·9016	·0708	·4003	·299	·399
	17	316·3096	−·0003	·2991	·4685	·8186	·097	·838
	27	99·4857	−·0005	·6966	·8662	·2368	·896	·277
1893.								
Jan.	6	242·6618	−·0007	·0941	·2638	·6551	·694	·716
	16	25·8379	09	·4916	·6615	·0734	·493	·155
	26	169·0140	11	·8891	·0591	·4916	·291	·594
Feb.	5	312·1901	13	·2866	·4568	·9099	·090	·033
	15	95·3662	15	·6842	·8544	·3281	·888	·472
	25	238·5423	17	·0817	·2521	·7464	·687	·911
Mar.	7	21·7184	−·0019	·4792	·6498	·1646	·485	·350

			Inclination. γ_3	Node. $O-\Gamma_3$				Inclination. γ_3	Node. $O-\Gamma_3$
			°	°				°	°
1892	May	11	0·1336	121·48	1892	Oct.	8	0·1319	122·02
	June	10	·1333	121·57		Nov.	7	·1315	122·15
	July	10	·1330	121·67		Dec.	7	·1311	122·29
	Aug.	9	·1326	121·78	1893	Jan.	6	·1307	122·44
	Sept.	8	·1322	121·90		Feb.	5	·1303	122·59
	Oct.	8	0·1319	122·02		Mar.	7	0·1299	122·75

Greenwich Noon. 1892.		Third Satellite. Arguments. ζ_3	η_3	θ_3	ι_3	Fourth Satellite. Longitude. l_4—O	$\mathfrak{B}_4$	Arg. ϵ_4
May	21	·163	·584	·418	·872	251°·3648	−°·0011	·28925
	31	·185	·605	·438	·269	107·0755	15	·88839
June	10	·207	·625	·459	·665	322·7863	20	·48753
	20	·228	·646	·479	·062	178·4970	24	·08667
	30	·250	·667	·500	·458	34·2077	29	·68581
July	10	·272	·688	·521	·855	249·9185	−·0034	·28496
	20	·294	·708	·541	·251	105·6292	38	·88410
	30	·315	·729	·562	·648	321·3400	43	·48324
Aug.	9	·337	·750	·582	·044	177·0507	48	·08238
	19	·359	·771	·603	·441	32·7614	52	·68152
	29	·381	·791	·624	·837	248·4722	57	·28067
Sept.	8	·402	·812	·644	·234	104·1829	−·0062	·87981
	18	·424	·833	·665	·630	319·8937	66	·47895
	28	·446	·854	·685	·027	175·6044	71	·07809
Oct.	8	·468	·874	·706	·423	31·3151	75	·67723
	18	·489	·895	·727	·820	247·0259	80	·27637
	28	·511	·916	·747	·216	102·7366	85	·87552
Nov.	7	·533	·937	·768	·613	318·4474	−·0089	·47466
	17	·555	·957	·788	·009	174·1580	·0094	·07380
	27	·576	·978	·809	·406	29·8688	·0098	·67294
Dec.	7	·598	·999	·829	·802	245·5796	·0103	·27208
	17	·620	·020	·850	·199	101·2903	·0107	·87123
	27	·642	·040	·871	·595	317·0011	·0112	·47037
1893.								
Jan.	6	·663	·061	·891	·992	172·7118	−·0117	·06951
	16	·685	·082	·912	·388	28·4225	·0121	·66865
	26	·707	·102	·932	·785	244·1333	·0126	·26779
Feb.	5	·729	·123	·953	·181	99·8440	·0130	·86694
	15	·750	·144	·974	·578	315·5548	·0134	·46608
	25	·772	·165	·994	·974	171·2655	·0139	·06522
Mar.	7	·794	·185	·015	·371	26·9762	−·0143	·66436

1892.		Inclination. γ_4	Node. O—Υ_4
May	11	0°·3489	29°·15
June	10	·3491	29·12
July	10	·3493	29·08
Aug.	9	·3495	29·04
Sept.	8	·3496	29·00
Oct.	8	0·3497	28·95

Fourth Satellite.

Greenwich Noon. 1892.	Arguments. β_4	γ_4	δ_4	ϵ_4	ζ_4	η_4	θ_4
May 21	·328	·623	·819	·108	·539	·364	·206
31	·127	·222	·414	·302	·739	·581	·405
June 10	·925	·821	·008	·496	·938	·797	·605
20	·724	·420	·603	·690	·137	·014	·804
30	·523	·019	·198	·883	·337	·231	·004
July 10	·321	·618	·792	·077	·536	·448	·203
20	·120	·217	·387	·271	·735	·664	·403
30	·918	·816	·981	·465	·935	·881	·602
Aug. 9	·717	·415	·576	·658	·134	·098	·802
19	·515	·014	·171	·852	·334	·315	·001
29	·314	·613	·765	·046	·533	·531	·201
Sept. 8	·112	·212	·360	·240	·732	·748	·400
18	·911	·811	·955	·434	·932	·965	·600
28	·709	·410	·549	·627	·131	·182	·799
Oct. 8	·507	·009	·144	·821	·330	·398	·999
18	·306	·608	·739	·015	·530	·615	·198
28	·105	·207	·331	·209	·729	·832	·398
Nov. 7	·903	·806	·928	·402	·929	·049	·597
17	·702	·405	·522	·596	·128	·266	·797
27	·500	·004	·117	·790	·328	·482	·996
Dec. 7	·299	·603	·712	·984	·527	·699	·196
17	·097	·202	·306	·178	·726	·916	·395
27	·896	·801	·901	·371	·925	·133	·595
1893. Jan. 6	·694	·400	·496	·565	·125	·349	·795
16	·493	·999	·090	·759	·324	·566	·994
26	·291	·598	·685	·953	·524	·783	·194
Feb. 5	·090	·197	·280	·146	·723	·000	·393
15	·888	·796	·874	·340	·922	·216	·593
25	·687	·395	·469	·534	·122	·433	·792
Mar. 7	·485	·994	·063	·728	·321	·650	·992

		Inclination. γ_4	Node. $\Omega - \Gamma_4$
1892 Oct.	8	0°·3497	28°·95
Nov.	7	·3497	28·90
Dec.	7	·3498	28·84
1893 Jan.	6	·3498	28·79
Feb.	5	·3497	28·73
Mar.	7	0·3496	28·68

Col. Cooper's Observatory:
Markree, Collooney, Ireland.

Note on the Conjunction of Venus and Jupiter observed in Australia, 1892 February 6. By A. Marth.

Mr. Russell, the Director of the Sydney Observatory, has been good enough to send me some letters which he has received referring to the conjunction of *Venus* and *Jupiter* on February 6. The weather in general seems to have been unfavourable. At Sydney "a dense mantle of cloud blotted out the planets the whole evening." But in some parts of New South Wales the sky has been more propitious and very clear.

At Gara Station, about ten miles from Armidale (lat. 30° 32′ S., long. 151° 38° E.), Mr. R. P. Sellors and a party of friends saw the planets separate till about $7^h\ 35^m$ Sydney M. T., but by $7^h\ 45^m$ they appeared as one.

At Monteagle, Bathurst, Mr. J. B. Dulhunty and a party of friends watched the two planets approaching conjunction, and at $7^h\ 40^m$ Sydney M. T. could not tell whether they did not appear to the naked eye as one star.

The distances between the rim of *Jupiter* and the nearest edge of the illuminated disc of *Venus* at the two times recorded at Gara Station were 98″ and 74″, so that the distance of the two edges at which the eyes of Mr. Sellors and his friends ceased to separate the two planets is between these limits.

Preliminary Address of the General Committee of the World's Congress Auxiliary on Mathematics and Astronomy.

The following circular has been received from Professor G. E. Hale:—

"The World's Congress Auxiliary is an organisation maintained by the World's Columbian Exposition, and approved by the Government of the United States, for the purpose of organising a series of Congresses or Conventions to be held during the progress of the Exposition in 1893, and which will bring together the leading scholars of the world for the mutual interchange of ideas on topics bearing on human progress.

"A scientific Congress to present and consider investigations in its special lines of research from all parts of the world, cannot fail to exert an important influence in the progress of scientific development. The personal interchange of views in regard to methods of observation and investigation will undoubtedly be productive of mutual benefit to the members of the Congress, as well as of lasting value to science.

"The General Committee on Mathematics and Astronomy presents this Preliminary Address, cordially inviting the co-operation of all persons and societies interested in this department of physical science.

"As the matter assigned to this committee covers a large field in physical science, it has been thought advisable to arrange the subjects to be considered under the following chapters and sections, in which, in consideration of its recent development and growing importance, astro-physics has been assigned a separate chapter from other branches of general astronomy.

"The following are some of the topics suggested for consideration under the several chapters:—

"CHAPTER I.—*Pure Mathematics*. Section *a*, History and Bibliography; Section *b*, Arithmetic and Theory of Numbers; Section *c*, Analysis; Section *d*, Geometry; Section *e*, Analytical Mechanics; Section *f*, Mathematical Physics.

"CHAPTER II.—*Astronomy*. Section *a*, History of Astronomy; Section *b*, Astronomical Instruments; Section *c*, Methods of Observation; Section *d*, Physical Astronomy; Section *e*, Observatory Buildings.

"CHAPTER III.—*Astro-physics*. Section *a*, Spectrum Analysis; Section *b*, Astronomical Photography; Section *c*, Stellar Photometry.

"The object of this Preliminary Address is simply to bring the subject of the Congress to the notice of the scientific men of the world for advice and suggestions as to the general conduct of the convention, and in particular as to the scientific questions to be discussed. Recommendations of themes to be discussed and of persons to present them are especially solicited from the members of the Advisory Council of the Astronomical Congress. The Advisory Councils constitute the non-resident branches of the Auxiliary Committees. Additions to these Councils will be made from time to time. Communications may be addressed to the Chairman of the General Committee, or to the Chairman of the proper Special Committee.

"It is expected that men eminent in special lines of research will be invited to furnish papers on the leading topics under consideration. The suggestions and recommendations invited will be used in the formation of the programme for the Congress.

"The Chairmen of the Special Committees of the several chapters under the charge of the General Committee are as follows:—

"*On Pure Mathematics*: Professor E. H. Moore, Chicago University, Chicago, Ill.

"*On Astronomy*: Professor G. W. Hough, Dearborn Observatory, North-western University, Evanston, Ill.

"*On Astro-physics*: Professor Geo. E. Hale, Kenwood Astrophysical Observatory, Chicago, Ill.

"George W. Hough, Chairman.
"Elias Colbert, Vice-Chairman.
"E. H. Moore.
"George E. Hale.
"G. A. Douglas.
"Malcolm McNeill.
"R. W. Pike.
"Geo. C. Comstock.
"W. W. Payne.

"Committee of the World's Congress Auxiliary on a Congress of Mathematicians and Astronomers.

"*World's Congress Headquarters, Chicago, March* 1892."

Erratum in Annual Report February 1892.

The Mr. Henry Lord Boulton, of Carácas, Venezuela, whose death was recorded among the obituaries of Fellows who had died during the year 1891 (*Monthly Notices*, vol. lii. page 212), was not a Fellow of the Society. His son, also Mr. Henry Lord Boulton, of the same address, was elected 1889 January 11.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LII. SUPPLEMENTARY NUMBER. No. 9

The Orbit of Flora; with Corrections to Brünnow's "Tafeln der Flora." By A. M. W. Downing, M.A.

The tabular places of *Flora* as given in the *Berliner Jahrbuch*, which are derived from Brünnow's Tables, are, and have been for several years past, considerably in error. With the view of obtaining an orbit from which more accurate places may be deduced, I have undertaken a discussion of the meridian observations of the planet made during the years 1865–1888 inclusive, and I now beg leave to communicate the results of this investigation to the Society.

The observations discussed are principally those made at Greenwich and at Paris. In cases where these are not sufficiently numerous I have availed myself of the results obtained at Hamburg (1881), Leiden (1870, 1872), and Washington (1872, 1879, 1883). These various series of observations have been reduced to a uniform system in the manner explained (in the case of observations of *Juno*) in *Monthly Notices*, vol. l. pp. 487–489. For the Paris observations, and for the Greenwich observations of R.A., the corrections adopted are those given on the pages referred to. To the Greenwich observations of declination the following corrections (corresponding to those given on p. 488 of vol. l.) have been applied:—

Year.	Dec.	Corr.	Year.	Dec.	Corr.
	°	″		°	″
1865	+10	−0·7	1873	+ 2	−1·0
1866	−21	−2·0	1875	+ 2	−1·0
1868	+20	−0·7	1876	−18	−1·6
1869	−17	−1·8	1879	−21	−0·6
1871	+21	−0·7	1881	+22	−0·1
1872	− 8	−1·3	1882	−16	−0·2

The later Greenwich observations require no correction.

The Hamburg observations of 1881 require a correction in R.A. of $-0^{s}\cdot02$.

The Leiden observations require corrections in—

	R.A.	Dec.
	s	"
1870	−0·04	−0·4
1872	−0·01	+0·1

The Washington observations require corrections in—

	R.A.	Dec.
	s	"
1872	−0·03	−0·2
1879	−0·05	+0·6
1883	−0·02	+0·4

My thanks are due to Professors Rümker and Bakhuyzen for their courtesy in giving me the necessary information as to the mode of reduction of the Hamburg and Leiden observations respectively. The corrections to the Washington observations have been deduced from a consideration of the published statements regarding their mode of reduction.

These corrections having been applied, the following errors of the Tables were formed for the mean date of the observations made near the time of each opposition of *Flora*, by plotting down the observed errors on each day of observation, and drawing a curve through the points thus obtained:—

Date.	$\Delta\alpha$.	$\Delta\delta$.
	s	"
1865 Mar. 21	− 2·51	+13·3
1866 July 11	− 3·72	+ 1·1
1868 Feb. 22	− 3·94	+10·2
1869 June 8	− 4·60	+14·1
1870 Dec. 29	− 6·28	− 9·0
1872 May 15	− 5·54	+28·5
1873 Nov. 8	− 8·07	−45·1
1875 Apr. 17	− 6·62	+41·7
1876 Aug. 24	−12·05	−46·8
1879 July 5	−11·20	+ 6·4
1881 Feb. 13	−10·76	+21·9
1882 June 9	− 9·42	+40·6
1883 Dec. 4	−12·75	−30·2
1885 May 12	− 8·90	+53·9
1886 Oct. 29	− 9·93	−58·4
1888 Apr. 12	− 8·76	+51·5

The equations connecting the variations of the elements of the orbit with the above errors were then formed in the usual manner, the adopted weights being simply the number of observations on which each absolute term in the equations depends.

The equations of condition for determining the required corrections to the elements are the following (where $dm = 1000\, d\mu$):—

Equations deduced from Right Ascensions.

								Weights.	Residuals.
1	+0·19363dπ	−8·59260dΩ	+9·74826di	+0·23185dφ	+0·09086dM	−0·71169dm	− 37″·1 = 0	8	+24″·5
2	+0·26416	−8·40637	+7·78746	−0·55926	+0·25880	−0·82588	− 51·9 = 0	6	+26·7
3	+0·22562	−8·64058	+9·38987	+0·48945	+0·19229	−0·68605	− 55·4 = 0	7	+14·0
4	+0·22913	+8·22115	+9·20839	−0·35740	+0·14233	−0·56291	− 65·8 = 0	6	+21·2
5	+0·29015	−7·56703	+8·10823	+0·57022	+0·36103	−0·67575	− 88·1 = 0	10	− 2·4
6	+0·19321	+8·25696	+9·65087	−9·87313	+0·06658	−0·26269	− 82·2 = 0	7	+ 6·0
7	+0·29027	+8·18752	+9·83821	+9·55908	+0·43192	−0·46367	−121·0 = 0	12	−15·6
8	+0·18068	−7·86629	+9·78672	+9·81111	+0·05322	−9·75438	− 99·2 = 0	7	− 6·8
9	+0·28412	−8·74476	+9·57691	−0·55111	+0·36166	+7·38751	−171·3 = 0	6	−38·1
10	+0·25852	−8·02243	−7·16137	−0·52943	+0·22887	+0·24851	−156·3 = 0	7	−19·4
11	+0·23730	−8·59295	+9·16873	+0·52767	+0·22716	+0·43695	−149·6 = 0	7	−23·4
12	+0·21549	+8·34986	+9·38223	−0·27768	+0·11502	+0·43791	−136·1 = 0	14	− 7·6
13	+0·29100	+7·86688	+9·01305	+0·51485	+0·38880	+0·81577	−182·3 = 0	4	−14·8
14	+0·18405	+8·15168	+9·71458	−9·59125	+0·05323	+0·55416	−132·8 = 0	6	− 8·5
15	+0·27295	−7·35793	+9·88193	−9·92580	+0·41399	+0·98265	−148·3 = 0	9	+43·9
16	+0·17897	−8·15685	+9·78420	+9·99044	+0·05709	+0·68421	−130·9 = 0	6	− 0·5

X X 2

Equations deduced from Declinations.

								Weights.	Residuals.
17	−9·78040$d\varpi$	−8·75266$d\Omega$	+0·15678di	−9·87123$d\phi$	−9·68623dM	+0·31021dm	+ 13″·3 = 0	8	− ″·7
18	+9·19117	+9·27321	−8·86082	−9·48705	+9·18718	−9·75395	+ 1·1 = 0	6	+ 1·7
19	−9·61358	−9·13893	+9·99278	−9·89734	−9·59521	+0·09315	+ 10·2 = 0	7	− 2·3
20	−9·47516	+9·16950	+9·96204	+9·55236	−9·37565	+9·80230	+ 14·1 = 0	5	− 6·6
21	+8·79588	−9·29232	−9·60531	+9·00368	+8·90309	−9·23117	− 9·0 = 0	10	+ 0·2
22	−9·72061	+8·90309	+0·13658	+9·23393	−9·58985	+9·79460	+ 28·5 = 0	7	− 4·7
23	+9·84989	−8·85576	−0·26204	−9·12743	+9·99123	−0·01796	− 45·1 = 0	12	− 2·8
24	−9·78143	+7·67302	±0·18001	−9·55128	−9·65712	+9·38550	+ 41·7 = 0	7	+ 3·9
25	+9·76375	+9·16388	−0·09637	−0·00231	+9·82706	−8·24674	− 46·8 = 0	6	−11·2
26	+8·09899	+9·26635	+9·31587	−8·46613	+8·15866	+8·24072	+ 6·4 = 0	8	+ 1·4
27	−9·50410	−9·19587	+9·89020	−9·80791	−9·51124	−9·71237	+ 21·9 = 0	7	+ 2·2
28	−9·58222	+9·12846	+0·00985	+9·70595	−9·47026	−9·79023	+ 40·6 = 0	13	+ 5·6
29	+9·32354	−9·24546	−9·99666	+9·40800	+9·44806	+9·86548	− 30·2 = 0	2	− 5·5
30	−9·74129	+8·80407	+0·14985	+8·75997	−9·60795	−0·10463	+ 53·9 = 0	6	+ 6·1
31	+9·85477	−8·35430	−0·27305	−9·77905	+9·99333	+0·55835	− 58·4 = 0	9	+17·2
32	−9·77557	−8·21696	+0·17661	−9·68365	−9·65862	−0·28239	+ 51·5 = 0	6	− 0·3

Proceeding to solve these equations by the method of least squares, the normal equations are found to be—

$$
\begin{array}{rrrrrrl}
+399{\cdot}970d\pi & -2{\cdot}031d\Omega & +\ 2{\cdot}594di & +\ 2{\cdot}305d\phi & +411{\cdot}440dM & +\ 0{\cdot}801dm & -25985{\cdot}21=0 \\
-\ 2{\cdot}031 & +1{\cdot}949 & +\ 3{\cdot}101 & +\ 0{\cdot}406 & -\ 1{\cdot}975 & +\ 0{\cdot}488 & +\ 193{\cdot}05=0 \\
+\ 2{\cdot}594 & +3{\cdot}101 & +208{\cdot}634 & +\ 6{\cdot}349 & +\ 2{\cdot}978 & +\ 6{\cdot}958 & +\ 30{\cdot}48=0 \\
+\ 2{\cdot}305 & +0{\cdot}406 & +\ 6{\cdot}349 & +716{\cdot}630 & +\ 15{\cdot}986 & -\ 207{\cdot}672 & +\ 2704{\cdot}66=0 \\
+411{\cdot}440 & -1{\cdot}975 & +\ 2{\cdot}978 & +\ 15{\cdot}986 & +446{\cdot}794 & +\ 35{\cdot}835 & -26969{\cdot}61=0 \\
+\ 0{\cdot}801 & +0{\cdot}488 & +\ 6{\cdot}958 & -207{\cdot}672 & +\ 35{\cdot}835 & +2673{\cdot}042 & -19641{\cdot}41=0
\end{array}
$$

whence the corrections to the assumed elements are—

$$
\begin{array}{llllll}
d\pi = & +63''{\cdot}994 & di = & -0''{\cdot}655 & dM = & +0''{\cdot}789 \\
d\Omega = & -31{\cdot}916 & d\phi = & -1{\cdot}897 & dm = & +7{\cdot}178
\end{array}
$$

The residuals given in the last column above have been formed by substituting these values in the equations of condition.

It is to be observed that in the equations of condition the coefficients are logarithms, whilst in the normal equations the coefficients are natural numbers.

The resulting mean elements of *Flora* are:—

Epoch of Mean Anomaly, 1876 August $24^{d}\cdot5$, Berlin M.T.

Mean anomaly, M	$= 313^\circ\ 21'\ 8''\cdot64$	
Long. of Perihelion, ϖ	$= 33\ 18\ 59\cdot63$	Mean Equinox and Ecliptic of 1876·0.
Long. of Node, Ω	$= 110\ 38\ 47\cdot24$	
Inclination, i	$= 5\ 53\ 0\cdot71$	
Angle of eccentricity, ϕ	$= 9\ 0\ 54\cdot39$	

Mean daily motion of M, $\mu = 1086''\cdot338160$

Log. Semiaxis Major, $\log a =$ 0·3426944

After repeated trials it was found to be impossible to sensibly reduce the residuals by further correction of the elements. It was decided, therefore, to adopt the above mean elements, and to seek for the means of obtaining a better agreement between the observed and computed places of the planet by a modification of the values of the perturbations as given by Brünnow's Tables. The direct method of treatment would have been, of course, to compute the special perturbations for the normal epochs, starting from the osculating elements corresponding to the mean elements given above. But considering the laborious (and therefore costly) nature of the work of computing special perturbations for a period extending over twenty-three years, I did not feel justified in undertaking it at the present time. And as I had not sufficient leisure to undertake the more personally exacting work of examining the formation and integration of the perturbational equations, I decided to endeavour to obtain empirical corrections to the coefficients in Brünnow's expressions for the general perturbations. By this means I hoped, at all events, to be able to ascertain whether the residuals could be so far represented by reasonable changes in the values of these coefficients as to establish the substantial accuracy of the adopted elements.

The periodic expressions for the perturbations, due to the action of *Jupiter* and *Saturn* (the only planets taken into account by Brünnow), are of the form

$$\begin{matrix} a \cos \\ b \sin \end{matrix} \left(l\mathrm{M} + m\,♃ + n\,♄ \right)$$

where a and b are numerical quantities, M, ♃, and ♄ the mean anomalies respectively of *Flora*, *Jupiter*, and *Saturn*, and

l, m, and n whole numbers (positive or negative) or zero. After a good deal of trouble it was found that the following corrections (which, of course, are not to be considered as rigorously determined) to Brünnow's values of a and b, in various terms occurring in the perturbations of the true anomalies, would reduce the residuals to quantities that might be considered satisfactory, considering all the circumstances of the case:—

Argument.	Corrections to a	Corrections to b	Argument.	Corrections to a	Corrections to b
M − ♃	+11″·6	+3″·1	2 (2 M − ♃)	− 0″·5	− 1″·2
2 (M − ♃)	− 7·2	− 1·4	M	− 2·0	− 0·7
3 (M − ♃)	− 0·7	+ 0·8	M − 3 ♃	+ 7·3	+ 2·5
− ♃	+ 3·5	− 2·1	3 M − 2 ♃	− 0·6	+ 1·0
2 (− ♃)	+ 1·0	− 5·9	3 M − 4 ♃	− 1·6	− 1·5
3 (− ♃)	− 0·8	+ 1·3	− M − ♃	− 1·1	− 0·5
M − 2 ♃	− 5·4	− 1·3	− M − 2 ♃	+ 2·1	+ 2·0
2 (M − 2 ♃)	− 1·5	− 2·1	M − 4 ♃	− 2·2	− 3·7
2 M − 3 ♃	+ 4·7	− 0·2	3 M − ♃	− 1·4	+ 0·3
2 (2 M − 3 ♃)	+ 1·9	− 6·0	M − ♄	+ 0·7	+ 0·2
2 M − ♃	+ 1·9	− 1·0			

It was not considered worth while proceeding with this part of the investigation farther, so as to obtain the corresponding corrections to the perturbations of the radius vector and of the coordinate z.

The above corrections were, therefore, applied to the perturbations of the true anomalies taken from the Tables (the other perturbations remaining unchanged), and geocentric places of *Flora* computed by their means, from the corrected elements, for the normal epochs.

These places were compared with "observed" places, obtained by applying the adopted errors of the Tables, given at the beginning of this paper, to the *Berliner Jahrbuch* places for the various dates. Thus the following errors of computed places were obtained:—

No.	Berlin Mean Time.	Δα	Δα cos δ	Δδ
	d	s	″	″
1	1865 Mar. 21·5	+0·24	+3·5	−2·3
2	1866 July 11·5	+0·19	+2·7	+0·7
3	1868 Feb. 22·5	−0·15	−2·1	+0·7
4	1869 June 8·5	−0·08	−1·1	−1·9
5	1870 Dec. 29·5	0·00	0·0	−2·9
6	1872 May 15·5	+0·17	+2·5	−4·0
7	1873 Nov. 8·5	+0·55	+8·2	+5·5
8	1875 April 17·5	0·00	0·0	−0·1
9	1876 Aug. 24·5	−0·45	−6·4	−0·3
10	1879 July 5·5	−0·36	−5·0	−0·1
11	1881 Feb. 13·5	+0·11	+1·5	−4·1
12	1882 June 9·5	+0·17	+2·5	+2·4
13	1883 Dec. 4·5	+0·31	+4·4	−3·9
14	1885 May 12·5	+0·03	+0·4	+1·7
15	1886 Oct. 29·5	+0·02	+0·3	+2·6
16	1888 April 12·5	−0·11	−1·6	−4·6

There is an *erratum* in the declination of *Flora* for 1869 June 8, as given in the *Berliner Jahrbuch* for 1871, where $-17° 27' 16''·5$ should read $-17° 27' 46''·5$.

For the convenience of astronomers who may wish to use the corrected elements of *Flora*, in combination with Brünnow's Tables, for the purpose of computing an Ephemeris, I append here continuations or modifications of certain of the Tables, or of parts of them, by means of which the necessary computations can be made with facility for the period 1892–1900.

My thanks are due to the Government Grant Committee of the Royal Society for a grant to defray the expenses of the computations connected with this investigation.

Continuation of Brünnow's Tafel I., "Argumente für die Jahre."

		I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.
B.	1892	222·59	17·12	239·71	102·30	68·07	205·5	256·8	290·7	324·9	171·6	188·8	273·9	273·5	205·9
	1893	302·41	346·80	289·20	231·61	258·03	315·6	275·9	200·5	174·0	31·1	18·0	262·8	213·6	4·8
	1894	22·23	315·47	338·70	0·92	87·99	65·8	295·1	110·2	23·1	250·6	207·2	251·6	153·7	163·7
	1895	102·04	286·15	25·19	130·23	277·95	175·9	314·3	20·0	232·3	110·2	36·4	240·5	93·8	322·6
B.	1896	182·08	255·74	77·82	259·90	108·43	286·4	333·5	290·6	81·9	329·4	225·2	229·3	34·7	120·8
	1897	261·90	225·41	127·31	29·21	298·39	36·5	352·7	200·4	291·0	188·9	54·4	218·2	334·9	279·7
	1898	341·72	195·09	176·80	158·52	128·35	146·6	11·9	110·1	140·2	48·5	243·6	207·0	275·0	78·6
	1899	61·54	164·77	226·30	287·83	318·31	256·8	31·0	19·9	349·3	268·0	72·8	195·9	215·1	237·5
	1900	141.35	134·44	275·79	57·14	148·27	6·9	50·2	289·6	198·5	127·5	262·0	184·7	155·2	36·4

		XV.	XVI.	XVII.	XVIII.	XIX.	XX.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.	XXVIII.
B.	1892	153·2	15·8	187·5	342·0	119·0	358·7	128·3	282·8	51·1	334·0	179·5	333·8	77·4	102·1
	1893	142·8	85·2	116·5	160·8	169·2	98·4	226·3	270·6	136·8	47·5	3·1	181·9	315·0	48·1
	1894	132·4	154·7	45·4	339·6	219·5	198·2	324·2	258·4	222·5	121·0	186·8	30·0	192·7	354·1
	1895	122·0	224·1	334·4	158·4	269·7	297·9	62·2	246·2	308·2	194·5	10·4	238·1	70·3	300·1
B.	1896	112·6	294·6	264·2	337·7	321·0	39·0	160·3	233·9	34·3	268·3	194·6	86·6	307·5	247·0
	1897	102·2	4·0	193·1	156·5	11·3	138·7	258·3	221·7	120·0	341·8	18·2	294·7	185·2	193·0
	1898	91·8	73·5	122·1	335·3	61·5	238·4	356·2	209·5	205·7	55·3	201·9	142·8	62·8	139·0
	1899	81·4	142·9	51·0	154·1	111·8	338·2	94·1	197·3	291·4	128·8	25·5	350·9	300·5	85·0
	1900	71·0	212·3	339·9	332·9	162·1	77·9	192·0	185·1	17·1	202·3	209·2	199·0	178·2	31·0

In the formation of these arguments the mean anomalies of *Flora* have been computed from the corrected elements. The mean anomalies of *Jupiter* and *Saturn* have been tàken from Le Verrier's Tables, and are corrected for the Great Inequality.

Table to be substituted for the First Part (page 6) of Brünnow's Tafel IV., "Für die mittlere Anomalie."

	M	t
	° ′ ″	
B. 1892	205 28 29·89	+44·000
1893	315 37 3·32	+44·999
1894	65 45 36·75	+45·999
1895	175 54 10·18	+46·998
B. 1896	286 20 49·94	+48·000
1897	36 29 23·37	+48·999
1898	146 37 56·80	+49·999
1899	256 46 30·23	+50·998
1900	6 55 3·66	+51·997

	M	t
	° ′ ″	
January	0 0 0·00	+0·000
February	9 21 16·48	+0·085
March	17 48 13·95	+0·162
April	27 9 30·43	+0·246
May	36 12 40·58	+0·329
June	45 33 57·06	+0·413
July	54 37 7·21	+0·496
August	63 58 23·69	+0·580
September	73 19 40·17	+0·665
October	82 22 50·32	+0·747
November	91 44 6·80	+0·832
December	100 47 16·95	+0·915

Days.	M	t
	° ′ ″	
1	0 18 6·34	+0·003
2	0 36 12·68	+0·005
3	0 54 19·01	+0·008
4	1 12 25·35	+0·011
5	1 30 31·69	+0·014
6	1 48 38·03	+0·016
7	2 6 44·37	+0·019
8	2 24 50·71	+0·022
9	2 42 57·04	+0·025
10	3 1 3·38	+0·027
20	6 2 6·76	+0·055
30	9 3 10·14	+0·082

In bissextile years (marked B above) subtract one day from the date during January and February.

Corrections to Brünnow's Tafel V., "Für die Mittelpunkts-Gleichung," and Tafel VI., "Für den elliptischen Radius Vector."

M	Δ(v−M).	Δ log. r.	M	Δ(v−M).	Δ log r.
°	″		°	″	
0	0·00	+27	90	−3·50	−29
1	−0·06	+27	95	−3·42	−32
5	−0·49	+26	100	−3·33	−34
10	−0·97	+25	105	−3·17	−37
15	−1·42	+23	110	−2·97	−40
20	−1·85	+21	115	−2·77	−40
25	−2·24	+18	120	−2·57	−40
30	−2·59	+15	125	−2·37	−41
35	−2·89	+11	130	−2·17	−43
40	−3·15	+ 7	135	−1·96	−46
45	−3·38	+ 3	140	−1·75	−49
50	−3·60	− 2	145	−1·54	−49
55	−3·70	− 5	150	−1·33	−49
60	−3·73	− 8	155	−1·12	−49
65	−3·74	−11	160	−0·91	−50
70	−3·75	−15	165	−0·70	−50
75	−3·69	−20	170	−0·48	−50
80	−3·63	−24	175	−0·25	−51
85	−3·57	−26	180	0·00	−51

These corrections reduce the Equation of the Centre and the log radius vector, taken from Brünnow's Tables, to the corresponding values deduced from the corrected elements.

The corrections for intermediate values of M can be found, with sufficient accuracy, by interpolation.

When M is greater than 180° the argument is 360°−M. In this case the sign of Δ $(v-M)$ must be changed, but the sign of Δ log r remains unchanged.

The values of Δ log r are expressed in units of the seventh decimal.

Continuation of Brünnow's Tafel XIV., "Für die Constanten in Bezug auf den Aequator."

	A	B	C	log a	log b	log c	log cos a	log cos b	log cos c
	° ′ ″	° ′ ″	° ′ ′						
1892	123 28 40·36	35 37 20·07	19 42 44·98	9·9979988	9·9694194	9·5738927	8·98127	9·55923n	9·96711
1893	123 29 30·75	35 38 9·19	19 43 36·69	9·9979992	9·9694233	9·5738660	8·98123	9·55921n	9·96711
1894	123 30 21·15	35 38 58·31	19 44 28·41	9·9979996	9·9694271	9·5738394	8·98119	9·55918n	9·96712
1895	123 31 11·55	35 39 47·44	19 45 20·13	9·9980000	9·9694310	9·5738127	8·98115	9·55916n	9·96712
1896	123 32 2·09	35 40 36·70	19 46 11·99	9·9980004	9·9694349	9·5737860	8·98110	9·55913n	9·96713
1897	123 32 52·48	35 41 25·82	19 47 3·72	9·9980008	9·9694387	9·5737594	8·98106	9·55911n	9·96713
1898	123 33 42·88	35 42 14·94	19 47 55·45	9·9980012	9·9694426	9·5737327	8·98102	9·55908n	9·96714
1899	123 34 33·28	35 43 4·07	19 48 47·18	9·9980016	9·9694464	9·5737061	8·98098	9·55906n	9·96714
1900	123 35 23·68	35 43 53·20	19 49 38·90	9·9980020	9·9694503	9·5736794	8·98093	9·55903n	9·96715

These quantities have been computed from the corrected elements, and the values of A, B, and C modified by subtraction of a constant (9′ 46″·5) from each, so as to be applicable to the perturbed true anomalies, when the perturbations are taken from Brünnow's Tables.

Nautical Almanac Office:
1892 *July* 26.

Greenwich Mean Times of Superior and Inferior Geocentric Conjunctions of Jupiter's Fourth Satellite (Callisto) from 1892 *November to the end of* 1893.

(*Communicated by the Superintendent of the "Nautical Almanac."*)

Attention having been drawn to the matter by Mr. Freeman in the current number of the *Observatory*, the following times of geocentric conjunctions of what has hitherto been known as *Jupiter's* Fourth Satellite are communicated to the Society, in the hope that they may be useful to observers generally.

The conjunctions of which the times are here given are geocentric conjunctions with the centre of the planet in the plane of the orbit of the satellite.

Superior Conjunctions.

1892.	d	h	m	1893.	d	h	m
Nov.	3	10	18·5	June	9	20	6·5
	20	1	13·0		26	16	37·0
Dec.	6	17	5·8	July	13	12	43·3
	23	10	3·1		30	8	17·0
1893. Jan.	9	4	2·1	Aug.	16	3	9·1
	25	22	55·6	Sept.	1	21	11·9
Feb.	11	18	33·8		18	14	16·2
	28	14	45·7	Oct.	5	6	18·5
Mar.	17	11	22·1		21	21	22·7
Apr.	3	8	15·3	Nov.	7	11	42·2
	20	5	16·5		24	1	43·6
May	7	2	19·5	Dec.	10	15	58·2
	23	23	18·7		27	6	53·1

Inferior Conjunctions.

1892.	d	h	m	1893.	d	h	m
Nov.	11	19	32·2	June	18	7	55·9
	28	10	56·4	July	5	4	12·5
Dec.	15	3	20·4		22	0	0·6
	31	20	47·5	Aug.	7	19	12·4
1893. Jan.	17	15	13·5		24	13	37·9
Feb.	3	10	28·1	Sept.	10	7	9·5
	20	6	22·0		26	23	41·5
Mar.	9	2	45·5	Oct.	13	15	12·7
	25	23	28·9		30	5	52·5
Apr.	11	20	24·7	Nov.	15	20	1·4
	28	17	26·3	Dec.	2	10	7·3
May	15	14	25·6		19	0	39·8
June	1	11	17·4	1894. Jan.	4	16	2·4

Nautical Almanac Office:
1892 *October* 5.

Observations of Phenomena of Jupiter's Satellites at Windsor, New South Wales, in the Year 1891.
By John Tebbutt.

Day of Obs. 1891.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m	Mean Time of *Nautical Almanac.* h m s
Aug. 20	III.	Tr. Egr.	Int. contact	8-inch	95	0 53 1	
20	III.	„	Bisection	„	„	0 57 6	1 2
20	III.	„	Ext. contact	„	„	1 1 20	
Sept. 2	II.	Ecl. D.	Last seen	„	170	23 59 53	23 59 39
3	I.	Tr. Egr.	Int. contact	„	„	0 32 8	
3	I.	„	Bisection	„	„	0 33 38	0 35
3	I.	„	Ext. contact	„	„	0 34 57	
10		Occ. D.	First contact	4½-inch	120	21 14 18	21 16
10	I.	„	Bisection	„	„	21 16 47	
10	I.	Ecl. R.	First seen	8-inch	170	23 41 1	23 40 58
11	I.	Tr. Egr.	Bisection	4½-inch	180	20 42 33	20 44
11	I.	„	Ext. contact	„	„	20 45 3	
11	Shd. I.	„	Int. contact	„	„	20 50 12	
11	Shd. I.	„	Bisection	„	„	20 52 12	20 55
11	Shd. I.	„	Ext. contact	„	„	20 52 57	

Day of Obs. 1892.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of *Nautical Almanac.* h m s
Sept. 11	II.	Tr. Ingr.	Ext. contact	4½-inch	180	21 1 15	
11	II.	„	Bisection	„	„	21 4 5	21 4
11	II.	„	Int. contact	„	„	21 5 40	
11	II.	Tr. Egr.	Int. contact	„	120	23 50 52	
11	II.	„	Bisection	„	„	23 51 42	23 55
11	II.	„	Ext. contact	„	„	23 55 1	
18	I.	„	Int. contact	8-inch	170	22 22 33	
18	I.	„	Bisection	„	„	22 25 22	22 28
18	I.	„	Ext. contact	„	„	22 27 32	
18	II.	Tr. Ingr.	Ext. contact	„	„	23 15 39	
18	II.	„	Bisection	„	„	23 18 28	23 21
18	II.	„	Int. contact	„	„	23 20 48	
20	II.	Ecl. R.	First seen	„	„	21 14 46	21 14 3
20	II.	„	Full brightness	„	„	21 16 46	
27	II.	„	First seen	„	„	23 49 31	23 49 40
27	II.	„	Full brightness	„	„	23 52 9	
Oct. 1	III.	Tr. Egr.	Int. contact	„	230	20 40 45	
1	III.	„	Bisection	„	„	20 44 15	20 48
1	III.	„	Ext. contact	„	„	20 48 44	

Day of Obs. 1891.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation.	Mean Time of *Nautical Almanac.*
						h m s	h m s
Oct. 3	I.	Ecl. R.	First seen	8-inch	230	23 55 41	23 55 41
3	I.	"	Full brightness	"	"	23 58 0	
4	I.	Tr. Egr.	Int. contact	"	"	20 19 42	
4	I.	"	Bisection	"	"	20 22 17	20 24
4	I.	"	Ext. contact	"	"	20 24 21	
4	II.	Occ. D.	First contact	"	"	22 9 14	
4	II.	"	Bisection	"	"	22 11 23	22 10
4	II.	"	Last seen	"	"	22 13 3	
8	III.	Tr. Ingr.	Ext. contact	"	130	20 51 11	
8	III.	"	Bisection	"	"	20 55 20	20 49
8	III.	"	Int. contact	"	"	20 59 14	
9	III.	Tr. Egr.	Int. contact	"	110	0 5 3	
9	III.	"	Bisection	"	130	0 8 33	0 13
9	III.	"	Ext. contact	"	"	0 13 32	
9	Shd. III.	Tr. Ingr.	Int. contact	"	"	0 14 32	0 6
10	I.	Occ. D.	First contact	"	170	22 43 14	
10	I.	"	Bisection	"	"	22 45 29	22 44
10	I.	"	Last seen	"	"	22 46 18	

Day of Obs. 1891.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of *Nautical. Almanac* h m s
Oct. 11	I.	Tr. Egr.	Int. contact	8-inch	170	22 7 6	
11	I.	„	Bisection	„	„	22 8 56	22 11
11	I.	„	Ext. contact	„	„	22 10 55	
12	I.	Ecl. R.	First seen	„	„	20 19 56	20 19 57
12	I.	„	Full brightness	„	„	20 21 44	
14	IV.	Occ. R.	Bisection	„	„	21 20 5	21 28
14	IV.	„	Last contact	„	„	21 22 49	
18	I.	Tr. Ingr.	Ext. contact	„	„	21 39 47	
18	I.	„	Bisection	„	„	21 41 37	21 40
18	I.	„	Int. contact	„	„	21 43 51	
29	II.	Ecl. R.	First seen	„	130	23 32 55	23 32 34
29	II.	„	Full brightness	„	„	23 35 55	
Nov. 1	IV.	„	First seen	„	...	0 5 44	0 9 30
1	IV.	„	Full brightness	„	...	0 16 28	
2	III.	Occ. D.	First contact	„	...	21 16 27	
2	III.	„	Bisection	„	...	21 18 37	21 17
2	III.	„	Last seen	„	...	21 21 6	

Day of Obs. 1891.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation.	Mean Time of *Nautical Almanac*.
						h m s	h m s
Nov. 2	I.	Occ. D.	First contact	8-inch	130	22 34 14	
2	I.	„	Bisection	„	...	22 37 29	22 38
2	I.	„	Last seen	„	...	22 39 43	
14	II.	Tr. Egr.	Int. contact	„	200	21 18 0	
14	II.	„	Bisection	„	„	21 20 15	21 24
14	II.	„	Ext. contact	„	„	21 22 29	
25	I.	Occ. D.	First contact	4½-inch	300	22 45 21	
25	I.	„	Bisection	„	„	22 47 6	22 46
25	I.	„	Last seen	„	„	22 48 26	
Dec. 16	II.	Tr. Egr.	Bisection	8-inch	130	21 12 38	21 11
16	II.	„	Ext. contact	„	„	21 14 58	
19	I.	„	Int. contact	4½-inch	180	22 29 16	
19	I.	„	Bisection	„	„	22 31 16	22 32
19	I.	„	Ext. contact	„	„	22 33 36	
27	I.	Ecl. R.	First seen	„	90	23 3 27	23 2 41
27	I.	„	Full brightness	„	„	23 5 14	

Remarks.

Aug. 20.—Fair definition.

Sept. 2.—Good definition. Satellite appeared as a narrow band of light parallel to the planet's limb.

Sept. 3.—Excellent definition; internal contact noted rather late.

Sept. 10.—Planet's limb boiled violently after the bisection. Sky beautifully clear at the reappearance, and the satellites perfectly tranquil circular discs. These measures with the filar micrometer, which were very consistent, gave $47''\!\cdot\!57$ as the polar diameter of the planet.

Sept. 11.—Satellite I. fairly defined, but there was a slight boiling at the egress of the shadow. Definition bad at ingress, but good at egress, of II.

Sept. 18.—Good definition throughout for I., and for first two phases of II. Images tremulous at internal contact of II.

Sept. 20.—Images steady and well defined, but seen through thin cloud.

Sept. 27.—The three satellites on the west side of the planet were circular, tranquil discs, but that next to the planet was very hazy and indistinct as compared with the brilliancy of the others.

Oct. 1.—Images steady and pretty well defined, but III. unusually faint at internal contact, and appeared oval along the limb.

Oct. 3.—Sky clear and Moon absent; definition pretty good.

Oct. 4.—Definition of I. pretty good and of II. excellent. Observations unusually good.

Oct. 8, 9.—Definition good throughout.

Oct. 10.—Definition pretty good at first contact, but bad at the two other phases.

Oct. 11.—Images very steady and beautifully defined. Observations made with unusual precision.

Oct. 12.—Clear sky, and strong twilight; images fairly defined, but rather tremulous.

Oct. 14.—Satellite faint and slightly dusky.

Oct. 18.—Images tremulous.

Oct. 29.—Sky clear, and steadiness and definition satisfactory.

Nov. 1.—Sky clear and definition good. During the reappearance the planet was occulted by one of the bars of the square micrometer. The recovery of light was so excessively slow that it was impossible to fix the time of full brightness with any approach to accuracy.

Nov. 2.—Images steady and well defined.

Nov. 14.—Excellent definition; internal contact noted late.

Nov. 25.—Definition pretty good, and sky hazy.

Dec. 16.—Images tremulous, and badly defined in strong twilight.

Dec. 19.—Sky beautifully clear, but definition bad.

Dec. 27.—Definition pretty good. Sky free from cloud, but slightly hazy from smoke.

Note.—With the exception of Nov. 1 an occulting bar was not employed in the observations of the eclipses for 1891. The times given in the first and seventh columns are the Windsor mean times of observation diminished by $10^h\ 3^m\ 20^s\!\cdot\!5$, and entered to the nearest second.

Private Observatory, Windsor, N. S. Wales.
1892 *June* 5.

Observations of U Orionis. By Lieutenant-Col. E. E. Markwick.

The following are my observations of the above star in 1892, made with a binocular magnifying five times:—

		m				m
Jan.	1	9	Just glimpsed.	1892 Feb.	1	6·37
	3	8·65			23	6·57
	5	8·2	Visible in moonlight.		24	6·57
	6	7·6			25	6·4
	21	6·27			26	6·8
	24	6·32		Mar.	22	7·9
	25	6·27			28	8·3
	27	6·32			30	8·8
	29	6·37				

The magnitudes are on the H.P. scale as nearly as may be. The maximum appears to have occurred about January 23; but the change of brightness of this star about this period is so slow that it is somewhat difficult to allocate the maximum with certainty. Assuming it to have been at maximum on December 13, 1885, when first discovered by Gore, we have an interval of 2,232 days to January 23 this year, during which six periods elapsed. Hence the mean period would be 372 days. As, however, this is perhaps rather a hazardous assumption, let us take 1886 December 12 as a well-determined maximum. This is the mean of four observers—viz. Gore, December 11; Markwick, December 16; Sawyer, December 13; and Parkhurst, December 9. From 1886 December 12 to 1892 January 23 is 1,868 days, or five periods, which will give the mean as 373·6 days. This last is identical with the first value given by Gore on p. 518, vol. l., of the *Monthly Notices*, and also only differs from his provisional value (373·47 days) by 0·13 day. This is, of course, on the assumption that all these periods are identical in length. If, as Chandler supposes, there is some slow, gradual lengthening or dwindling of the period by a periodic term, then a very much longer series of observations will have to be obtained before this can be definitely ascertained.

Haulbowline, Queenstown:
1892 *September.*

Observations of Swift's Comet (a 1892) and Winnecke's Periodic Comet, made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the East, or Sheepshanks, equatoreal, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

The observations are corrected for refraction, but not for parallax.

Swift's Comet (a 1892).

Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Appt. R.A. of ☄	Appt N.P.D. of ☄	Comp. Star.
1892. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
June 9 14 14 41	B.	+3 33·05	0·00	9·6573	−10 59·1	−0·1	0·5989	2	0 11 27·13	49 22 50·5	*a*
9 14 14 41	,,	+2 32·50	0·00	9·6573	−11 23·1	−0·1	0·5989	2	0 11 27·28	49 22 54·1	*b*
27 11 2 23	A.C.	+0 12·60	0·00	9·6998	+ 0 38·8	0·0	0·7817	3	0 41 4·54	44 14 19·8	*c*
30 10 30 51	,,	−0 2·50	−0·04	9·6888	−20 14·1	−1·1	0·8045	4	...	...	*d*
30 10 33 6	,,	−1 55·00	0·00	9·6907	+ 2 17·9	+0·2	0·8020	3	...	...	*e*

Winnecke's Comet.

Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log factor of Parallax.	No. of Comps.	Appt. R.A. of ☄	Appt N.P.D. of ☄	Comp. Star.
1892. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
June 27 10 35 7	A.C.	−0 21·73	−0·13	9·5979	+11 48·9	+1·9	0·8544	2	9 6 22·72	54 38 42·7	*f*

Comparison Stars.

	Star's Name.	Mean R.A., 1892·0.	Mean N.P.D., 1892·0.	Authority.
		h m s	° ′ ″	
a	23 Andromedæ	0 7 54·18	49 33 39·7	Greenwich Observations, 1888 and 1889.
b	Piazzi O., 13	0 8 54·88	49 34 7·3	Greenwich Observations, 1887 and 1888.
c	O.A. (N.) 728	0 40 51·62	44 13 33·3	Second Armagh Catalogue, 1875, and Paris Catalogue, 1882.
d	B.D. +45°, 215	0 44 56·5	43 52	Bonn Observations, vol. v.
e	B.D. +46°, 189	0 46 51·8	43 28	,, ,, ,,
f	W.B. (2) IX., 70, 71, 72	9 6 44·67	54 27 0·7	Weisse's Bessel, vol. ii.

Notes.

Star *f* is a close triple star, the components being nearly equal. The mean of their places has been used, as the triplicity was not noticed with the low power employed. Winnecke's comet was very bright on June 27, and was readily visible in spite of the bright twilight.

The following meridian observations of Swift's comet were made with the Transit Circle :—

Greenwich Mean Solar Time.	Observer.	R.A.	N.P.D. (Corrected for Refraction and Parallax.)
1892. d h m s		h m s	° ′ ″
Aug. 30 14 4 47	A.C.	0 43 39·37	37 14 9·80
Sept. 3 13 44 11	,,	0 38 45·83	37 32 12·73

In computing the parallax log Δ was taken as 0·2676 on August 30, 0·2700 on September 3, these values being interpolated from Archenhold's Ephemeris.

The initials A.C. and B. are those of Mr. Crommelin and Mr. Bryant respectively.

Sextant Observations of Swift's Comet made on board the Ship "Eaton Hall." By Capt. G. M. Lourison.

(*Communicated by the Secretaries.*)

1892 April 6, position at noon, lat. 17° 30′ S., long. 27° 53′ W. 4 A.M., moderate E. to E. by N. breezes and clear sky. 5 A.M., altitude of comet 42° 40′ 47″; G.M.T., $19^h\ 1^m\ 24^s$. Distance from *Vega*, 53° 8′ 0″; *Mars*, 34° 52′ 0″; *α Centauri*, 91° 18′ 0″. Noon, brisk E. to E. by N. winds and clear sky. At 5 A.M., while observing the comet, a brilliant meteor shot from under it, illuminating the whole sky, and leaving a train of light which lasted a full minute and a half. The tail of the meteor was spiral as it fell.

INDEX.

LIST OF PRESENTS

RECEIVED DURING THE SESSION OF 1891–92,

AND OF

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MONTHLY NOTICES

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The present number of the *Monthly Notices* being the last of Vol. LII., Subscribers (not Fellows) are requested to take notice that the subscription for Vol. LIII., 10*s*., including postage, has now become due, and it is also requested that it may be forwarded to the Assistant-Secretary, Mr. W. H. Wesley, Burlington House, London, W., on or before the 1st December next; otherwise it will be considered that the subscription has not been renewed.

Fellows of the Society are informed that post-cards containing the titles of papers to be read at the evening meetings will be sent to those who shall express their wish to receive them. Fellows desiring to receive the post-cards are requested to send their names to the Assistant-Secretary, Burlington House, London, W.

In order to enable the Secretaries to prepare complete lists in time for the issue of the post-cards, authors are particularly requested to send in their papers not later than the Tuesday preceding the day of meeting.